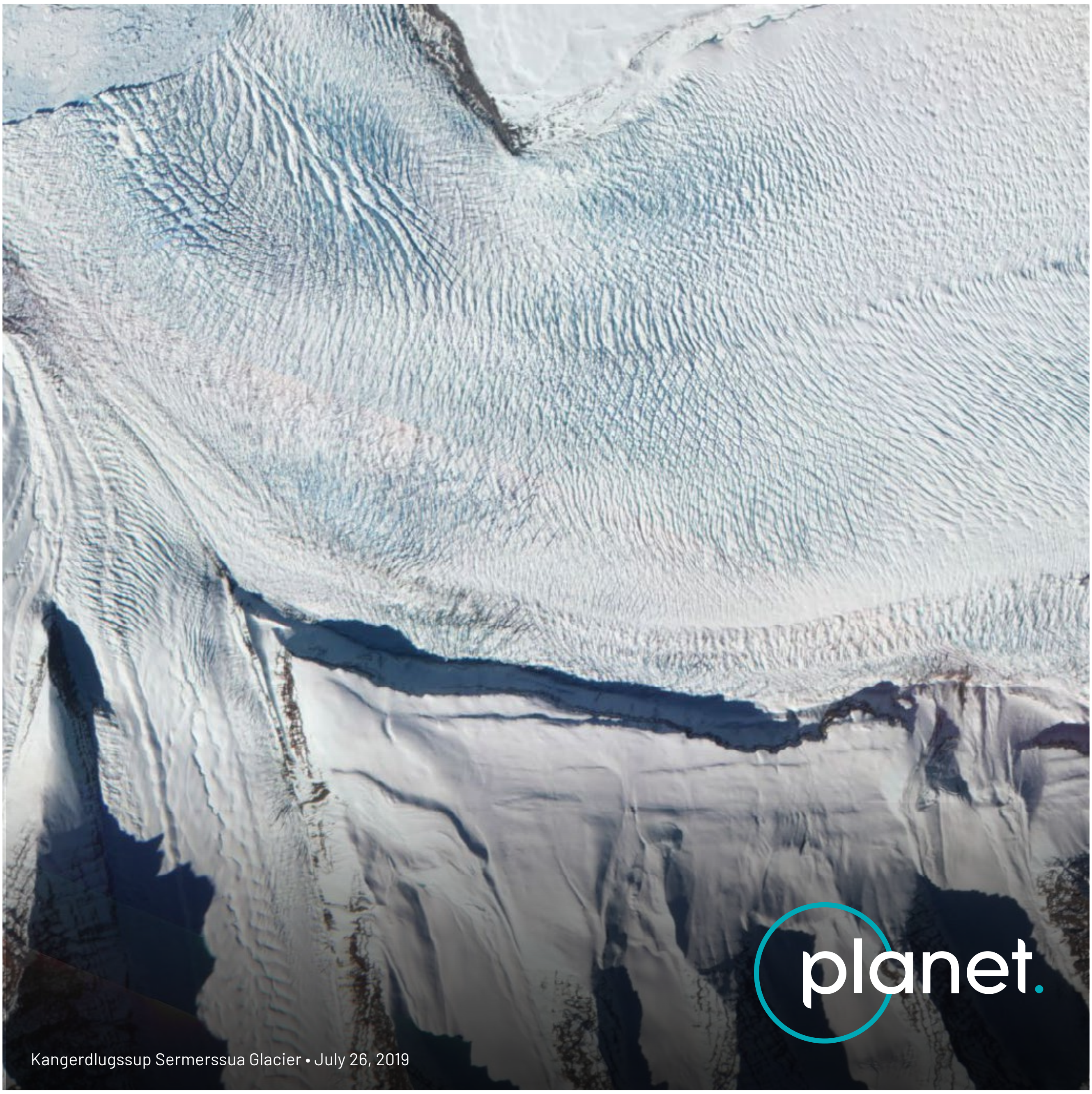
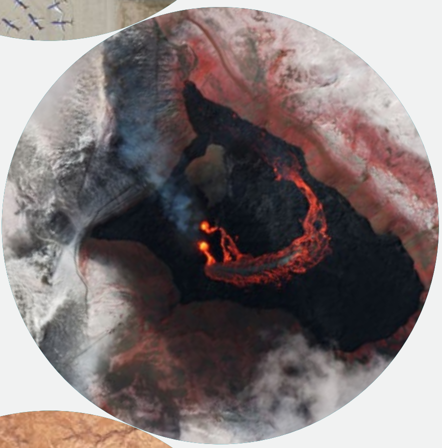
Planet Science Applications

2020-2021



Kangerdlugssup Sermerssua Glacier • July 26, 2019

go.planet.com/research



1/INTRODUCTION

Big Sur, California
February 4, 2021

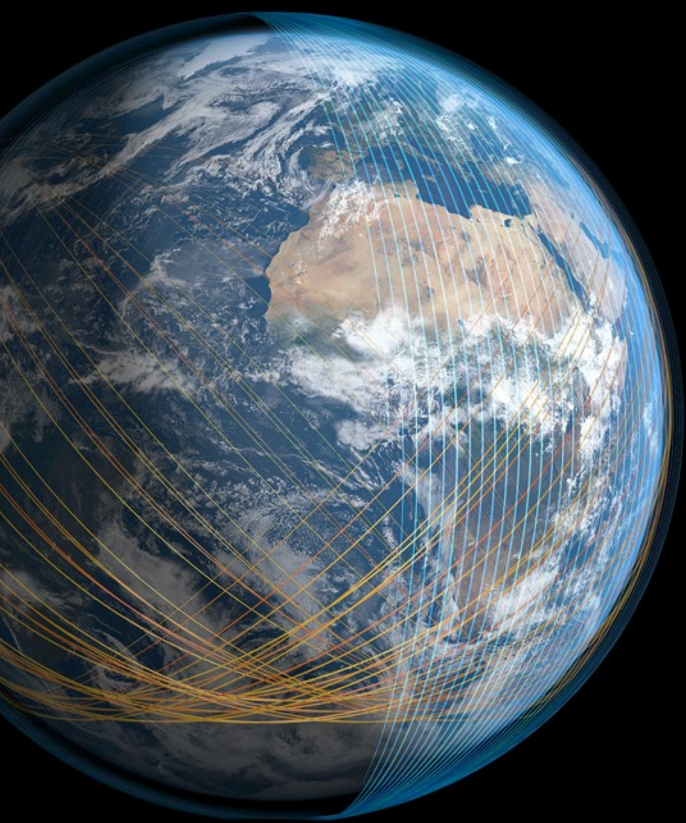
Planet

Planet is an integrated aerospace and data analytics company that operates history's largest commercial fleet of Earth observation satellites, collecting near-daily, high resolution imagery of the world.

Founded in 2010 by three NASA scientists, Planet operates approximately 200 satellites (Dove/PlanetScope and SkySat) in low Earth orbit, and develops the online software and tools that serve data to users. Planet's constellation of satellites capture imagery over the whole earth landmass, coral atolls and nearshore coastal environment at a near-daily cadence.

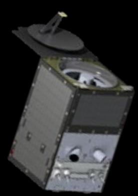
Decision makers in business, government and academia use Planet's data and machine learning-powered analytics to develop new technologies, power research, and solve our world's toughest challenges. Planet's capabilities are uniquely proven by our space-based constellation and automated image processing pipeline that includes both remote-sensing and machine-learning analytics.

Planet's Satellites



Dove Satellites

SATELLITES	GSD	CAPACITY
180+	**3.7 m**	**350 M km²**/day 8 band



SkySat Satellites

SATELLITES	GSD	CAPACITY
21	**0.65 m**	**400 K km²**/day 5 band

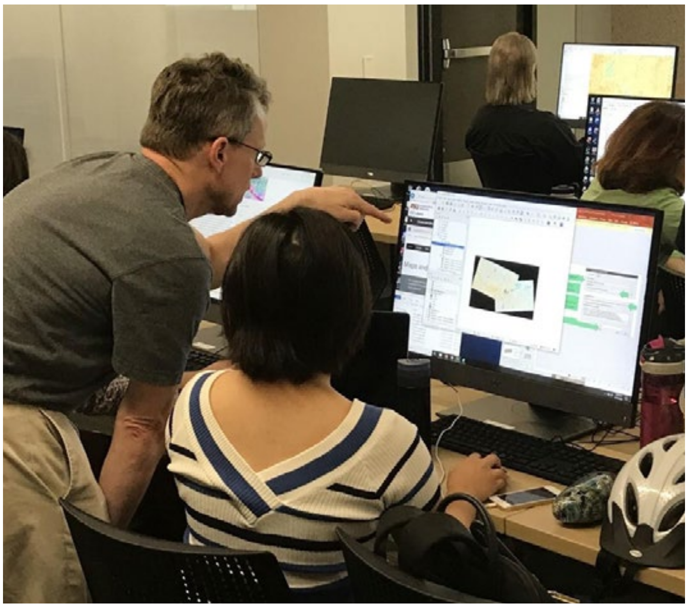
Planet's current constellation collects the landmass of the Earth and its coastal environments at a near-daily cadence.

Science & Education at Planet

Planet has invested in a rigorous, science-first platform, producing an unprecedented volume of calibrated remote sensing data — approximately 25 TB per day. Across the scientific community, from universities to NASA, ESA and the German Aerospace Centre, students and researchers have used Planet data to publish over 1,500 journal and conference papers, and have presented scores of talks and research seminars at academic conferences.

The breadth of research applications of Planet's dataset spans the whole Earth system, from the snow and ice covered regions of the high Arctic and Antarctic, to the jungles of Southeast Asia, to smallholder maize fields in Ethiopia. With each project, researchers are tapping into new methods and analytic tools to better understand natural ecosystems, and the human-used lands that replace them. Many of the projects featured here utilize machine learning, deep learning, and other AI tools to achieve results. Perhaps most critically, Planet research activities have infused classrooms by professors and educators who have identified the learning potential of this new approach to remote sensing.

Through our customer and philanthropic network, Planet is committed to scaling applications that provide the greatest benefit to the largest amount of people. We are confident the methods described herein will be used commensurate with Planet's founding intent: to use space to help life on Earth.



Dave Knapp, lead scientific software engineer at the Center for Global Diversity and Conservation Science at Arizona State University, leads a student workshop for analysis of Planet imagery. Photo by Joe Mascaro.

Accessing Data

Education and Research Program

Through our Education and Research Program, Planet provides university access to PlanetScope and RapidEye imagery (up to 5,000 square kilometers per month) for non-commercial research applications by application. The Education and Research Program hosts more than 10,000 users across 70 countries and more than 1,000 universities. To access this data source, users can apply at go.planet.com/research.

NASA Commercial SmallSat Data Acquisition (CSDA) Program

Through this program, all researchers funded by a U.S. federal civilian agency or the National Science Foundation have access to Planet's vast archive of PlanetScope and RapidEye imagery for scientific use and Earth science applications for societal benefit. For more information on the program and how to apply, visit go.planet.com/nasa.

European Space Agency Earthnet Program

Any researcher, including nonprofit researchers and those at government institutions or non-commercial early adopters, may apply for access to PlanetScope, RapidEye and SkySat imagery through the European Space Agency Category 1 Portal.

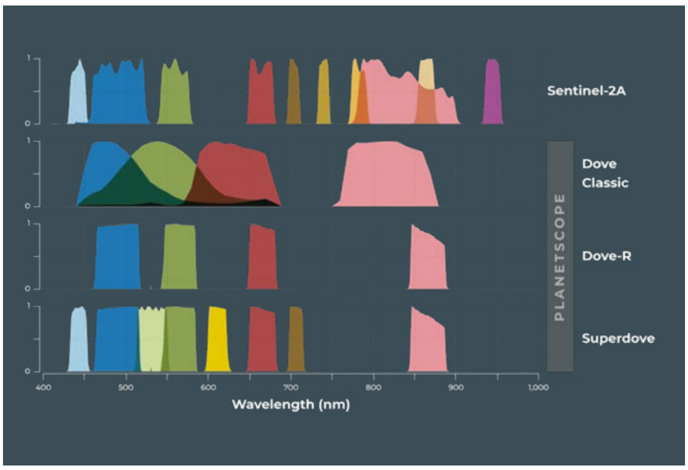
RapidEye Science Archive

Any German researcher, including nonprofit researchers and those at government institutions, may apply for access to PlanetScope, RapidEye and SkySat imagery through the RapidEye Science Archive.

Evolution of the Dove Radiometry

Planet's approach to agile aerospace allows us to design, build, and launch imaging satellites faster than any company or government in history by using lean, low-cost electronics and design iteration.

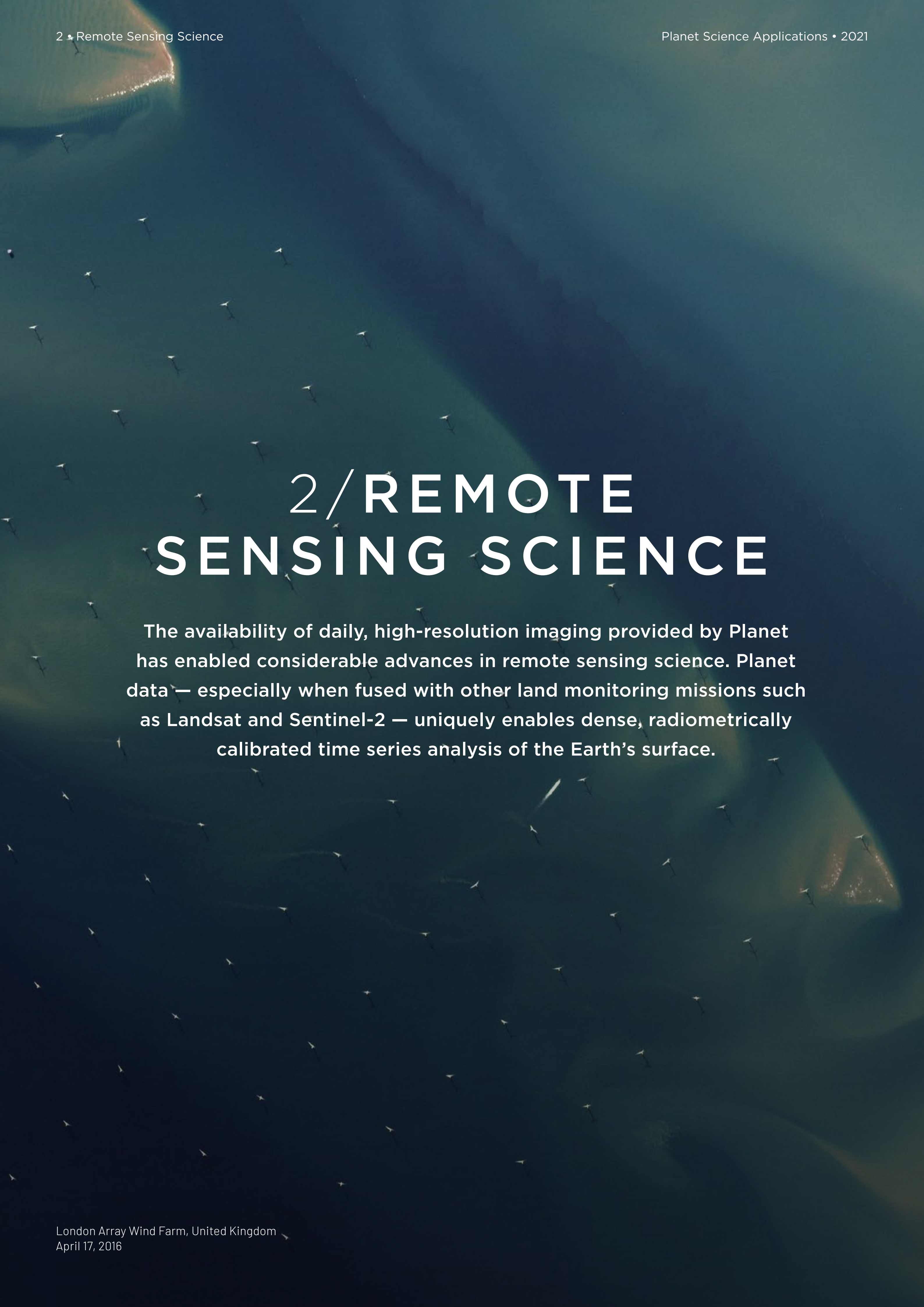
Since daily imaging began in 2017, Planet has continuously iterated to improve our Dove image quality and radiometric calibration. In the latest update, Planet is now operating the SuperDove platform, which images in 8 spectral channels, and for which most channels are aligned with the band passes of Sentinel-2 in order to improve interoperability (Huang and Roy, 2021).



Planet has refined and improved Dove satellite radiometry from Dove Classic (second row), to Dove-R (third row) to the 8-band SuperDove platform (bottom row). The coastal blue, blue, green I, red, red-edge and NIR channels are designed to be natively interoperable with Sentinel-2 (top row).

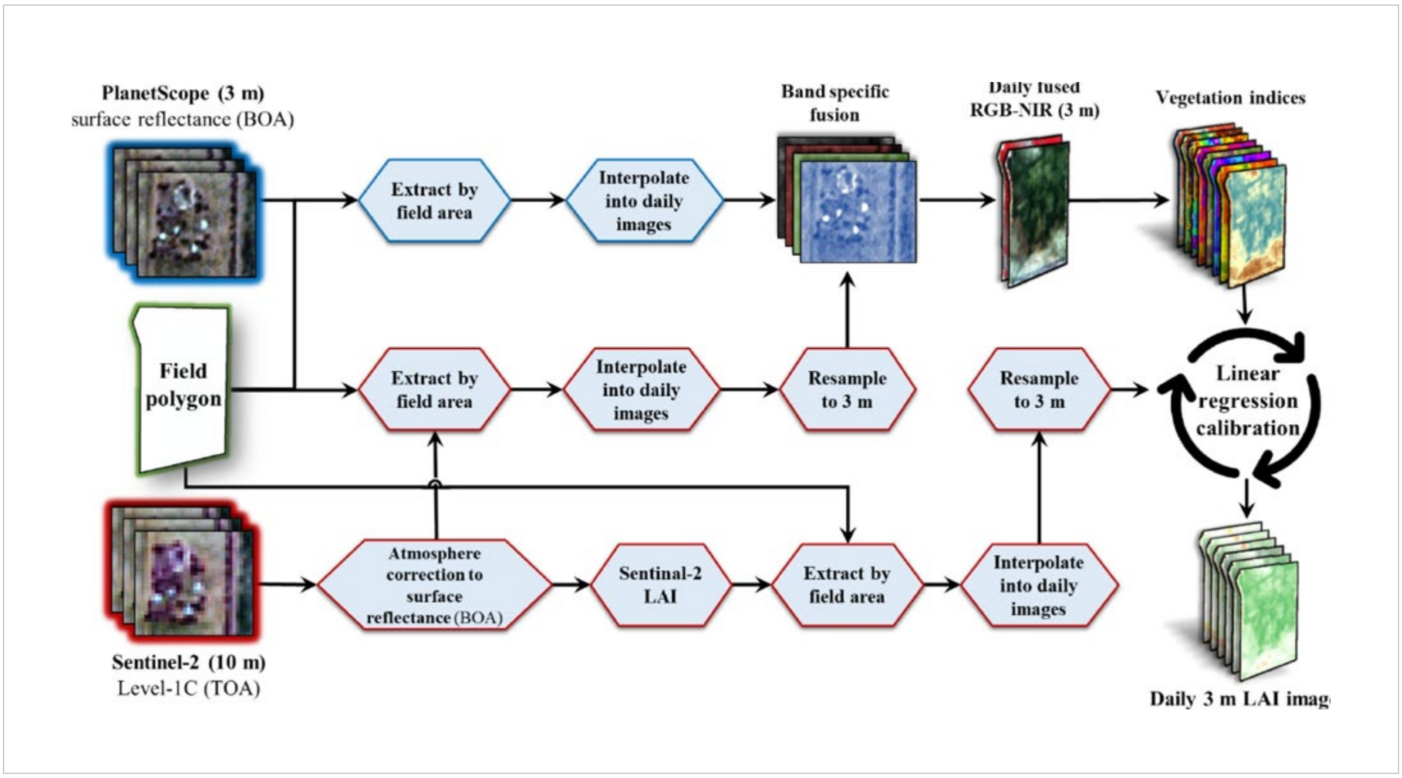
2/REMOTE SENSING SCIENCE

The availability of daily, high-resolution imaging provided by Planet has enabled considerable advances in remote sensing science. Planet data — especially when fused with other land monitoring missions such as Landsat and Sentinel-2 — uniquely enables dense, radiometrically calibrated time series analysis of the Earth's surface.



London Array Wind Farm, United Kingdom
April 17, 2016

Fusion of PlanetScope & Sentinel-2



Sadeh et al. (2021) fused PlanetScope with Sentinel-2 imagery to generate daily, ~3 m resolution Leaf Area Index estimates.

Improving crop yields, vigor and health can be facilitated by better monitoring of the cross-sectional area of vegetation — i.e., Leaf Area Index or LAI. However, measuring LAI on the ground is time consuming and expensive. Sentinel-2, operated by the European Space Agency, publishes a global LAI product; at 10 m resolution and a revisit of 5 days, however, Sentinel-based LAI estimates are limited in both spatial and temporal resolution.

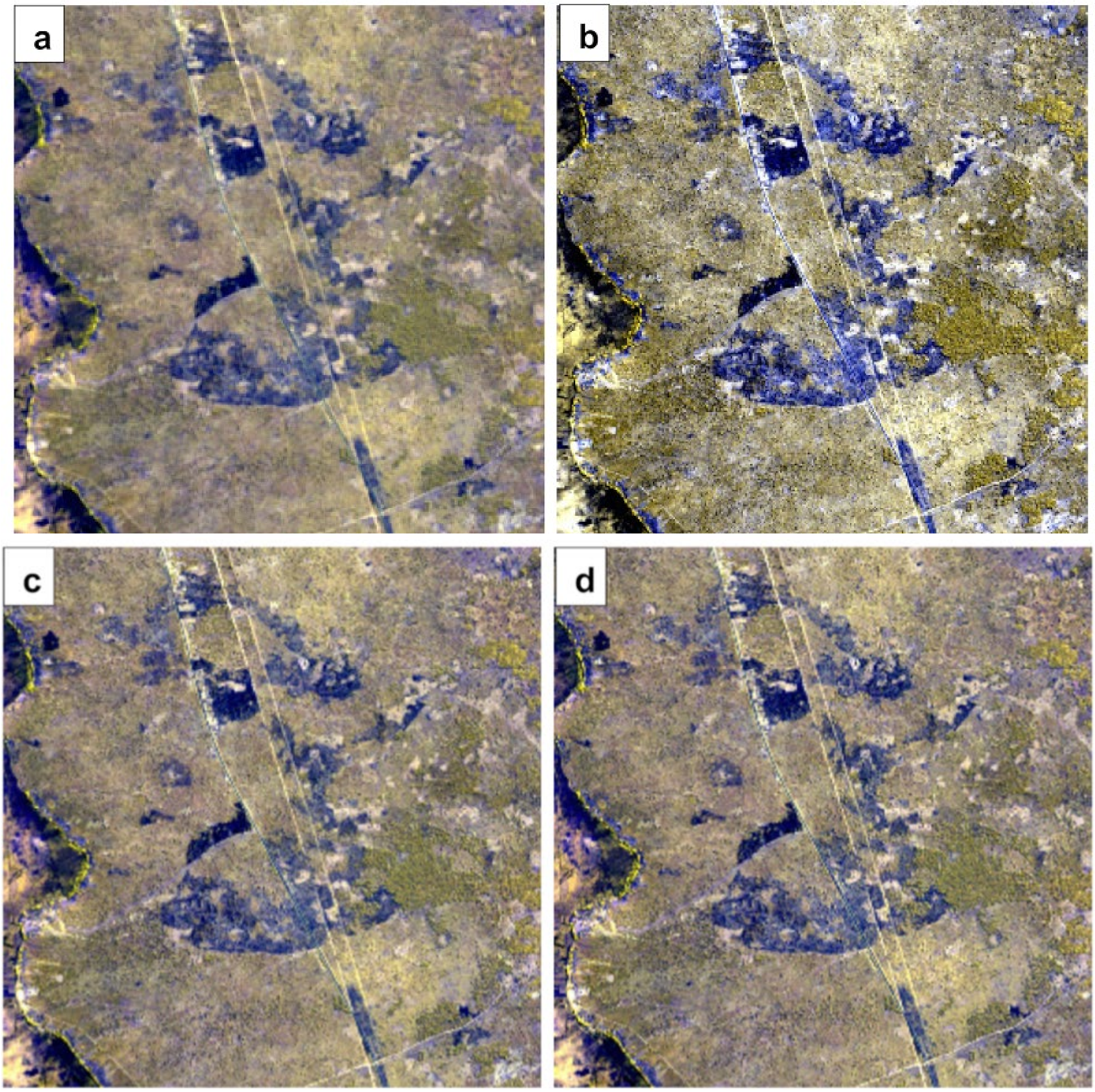
Yuval Sadeh and colleagues at Monash University in Australia fused PlanetScope data with Sentinel-2 to generate daily, ~3 m resolution LAI estimates. The results explained 94% of ground-measured LAI for validation sites in Israel and Australia. Sadeh et al. (2021) report that,

“These high spatio-temporal resolution time-series are valuable for monitoring crop growth and health, and can improve the effectiveness of farming practices and enhance yield forecasts at the field and sub-field scales.”

The study by Sadeh and team joins several recent efforts to fuse PlanetScope data with other passive optical sensors, combining the spectral fidelity of public assets such as Landsat and Sentinel-2 with Planet’s unique, daily high-resolution capabilities. As newer Planet spacecraft with improved radiometric sensitivity are increasingly deployed, even greater accuracy will be achieved.

Sharpening Sentinel-2 Data

Combining two datasets can produce a tertiary product better than the sum of its parts. Zhongbin Li and colleagues from Michigan State University fused PlanetScope ~3-m data with Sentinel-2 10- and 20-m data using high pass modulation (HPM) and the third modulation method (M3). Both HPM and M3 are well-established, computationally efficient methods to sharpen imagery while simultaneously reducing spatial distortion and maintaining the spectral properties of Sentinel-2 imagery. This fusion creates a daily ~3-m product with higher spectral fidelity than PlanetScope and higher spatial resolution than Sentinel-2. Li et al. (2020) applied this sharpening to the visible, red-edge, near-infrared, and short-wave infrared bands of Sentinel-2 covering study sites in Zambia. Comparing the results of the HPM and M3 methods to each other over each study location, they recommend that HPM be used for sharpening Sentinel-2 data with PlanetScope.



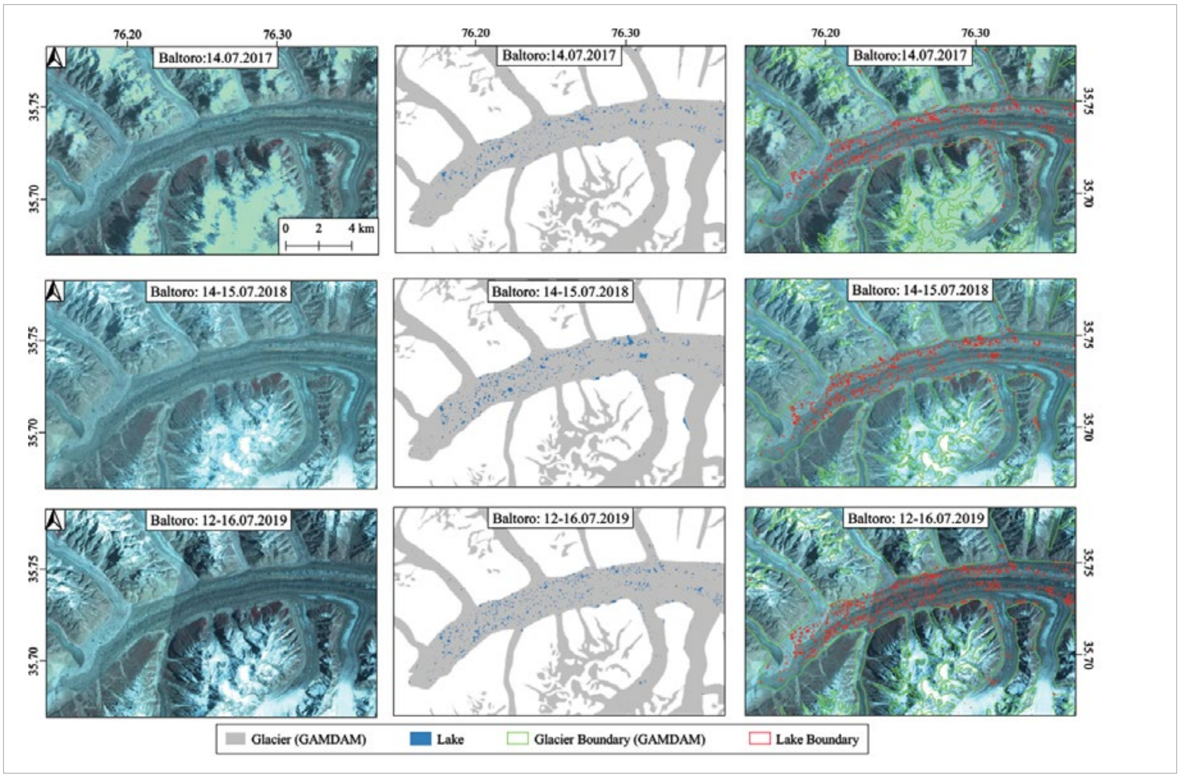
False color reflectance images from Li et al. (2020): (a) Sentinel-2 NIR + red edge + SWIR at the native 20-m resolution, (b) PlanetScope NIR + Sentinel-2 red edge + Sentinel-2 SWIR, (c) Sentinel-2 false color reflectance HPM sharpened to 3 m, and (d) Sentinel-2 false color reflectance M3 sharpened to 3 m.

3/CRYOSPHERE

Our global cryosphere is undergoing significant, rapid changes due to the impacts of climate change. The Arctic in particular is warming at twice the rate of the rest of our planet. Therefore, high spatial and temporal monitoring of these regions is of critical importance now more than ever to understand the extent of these changes, and their ecological and sociological impacts.

Milne Ice Shelf Collapse, Ellesmere Island, Canada
July 31, 2020

Glacial Risk Monitoring



Qayyum et al. (2020) used deep learning to map water bodies in glaciated terrain in the Himalaya and neighboring regions. This figure shows annual variations in the supraglacial lakes on the Baltoro glacier over the course of three years.

Glacial lakes in mountainous regions are prone to outburst floods that can devastate entire communities. With climate change, glacial ice is thinning and retreating in the Hindu Kush, Karakoram and Himalaya regions, posing an increasing threat to human lives and requiring improved, frequent monitoring.

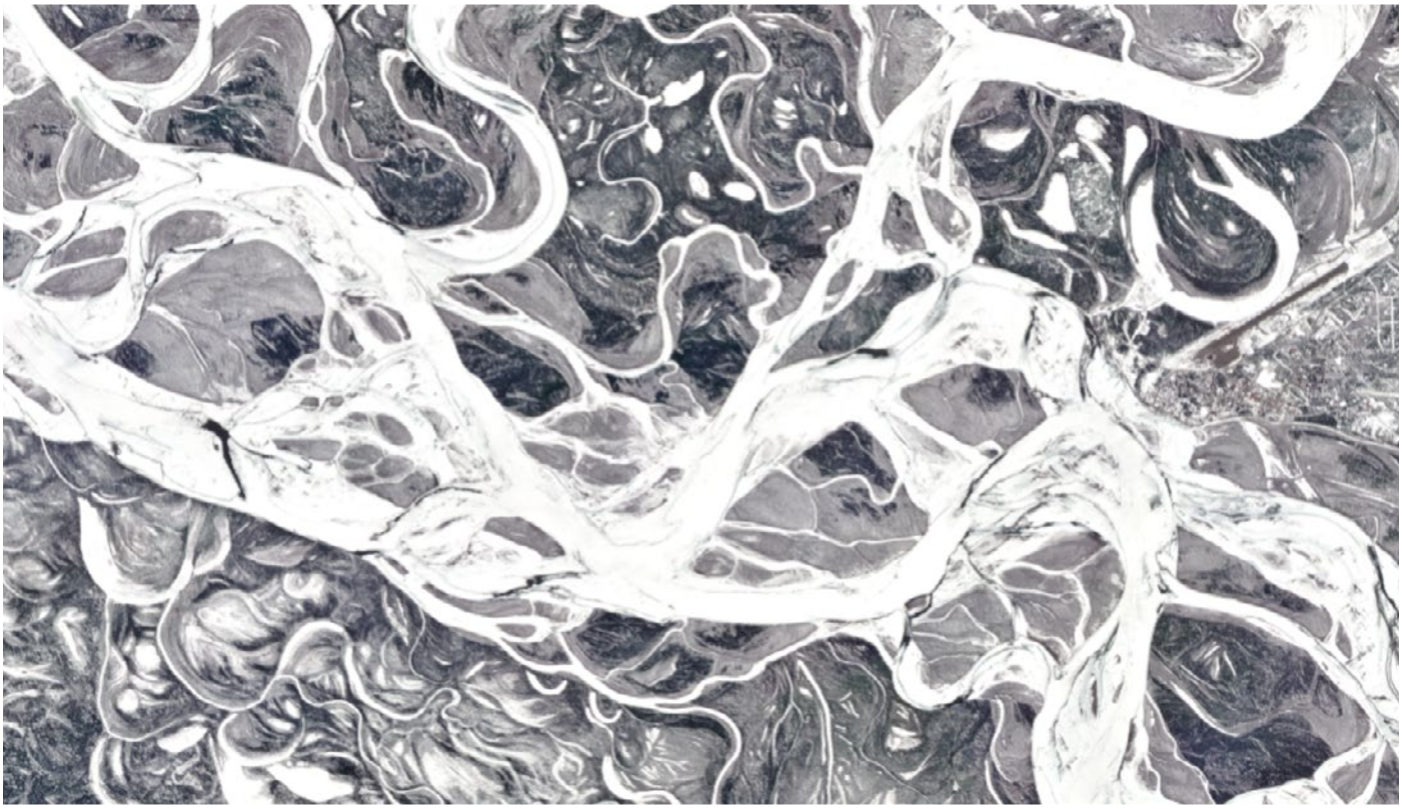
Nida Qayyum of the Department of Space Science at the Institute of Space Technology in Islamabad, Pakistan, led a collaborative study using deep learning and a dataset of 5,000 hand-digitized lakes in the region. She leveraged PlanetScope imagery, in combination with Landsat 8 and Sentinel-2 data.

Qayyum's team compared multiple machine learning approaches for accuracy in identifying new lakes, including a U-Net architecture (modified to ingest four spectral channels of PlanetScope), Random Forest, and Support Vector Machine classification. They reported that "the U-Net with EfficientNet backbone achieved the highest F1 Score of 0.936" and that "the deep learning model detected significantly more lakes than the existing inventories, which have been derived from Landsat OLI imagery."

"The results show that higher spatial and temporal resolution of PlanetScope imagery is a significant advantage in the context of glacial lakes mapping and monitoring," said the team.

Based on time-series analysis from known outburst floods, the authors argue the model will be valuable to mitigate future risk. Qayyum et al. conclude that "such events have occurred in the past and it is imperative to monitor such situations using remote sensing datasets. The automation of the whole process is essential as this region spreads over a large area and it is not possible to visually inspect the whole area."

Changes in Boreal Lakes



PlanetScope view of the Yukon Flats, Alaska, April 27, 2019.

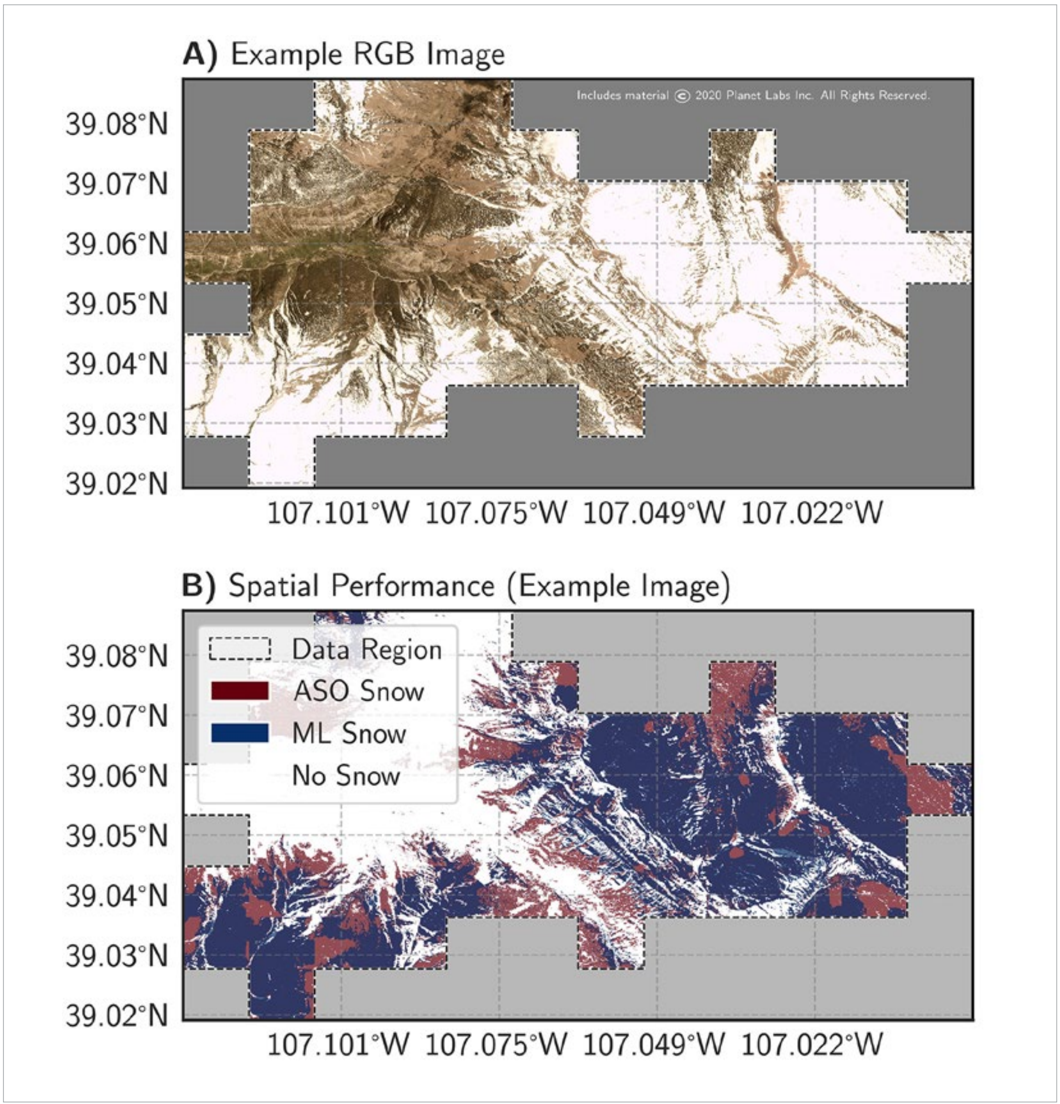
In Arctic and boreal regions, climate change is causing warming at twice the global average rate, leading to widespread changes to delicate eco-systems. One method for monitoring the impact on these ecosystems is to look at their gross primary production (GPP) — a measure of the conversion of inorganic carbon to biomass via photosynthesis.

Catherine Kuhn and colleagues from NASA's Arctic-Boreal Vulnerability Experiment (ABoVE) used PlanetScope, Sentinel-2, and Landsat 8 data along with aerial imagery to estimate the GPP of small lakes in the Yukon Flats of Alaska.

By combining remote sensing imagery with oxygen isotope measurements taken across some of the lakes in their study area, they were able to create an empirical model by which GPP could be estimated by analyzing the color of each lake in the optical imagery. They found that of all of the satellite datasets used, PlanetScope provided the best correlation with the ground-based GPP measurements thanks to its higher spatial resolution. "Shallow lakes are abundant worldwide and therefore the ability [to measure] GPP is crucial," the authors state, looking to expand their study area in the long term.

Mapping Snow Cover

Snow cover has ecological, hydrological, and economic impacts. Cannistra et al. (2021) used co-located PlanetScope and airborne LiDAR data to train a machine learning model to identify snow in the satellite imagery over the Gunnison Basin, Colorado. They ran the model over an area of the Tuolumne Basin without airborne LiDAR input. Their results show that PlanetScope offers unique insight into snow dynamics thanks to the combination of high spatial and temporal resolution. The authors note, "The unparalleled spatial and temporal coverage...offers an excellent opportunity for satellite remote sensing of snow, with real implications for ecological and water resource applications."



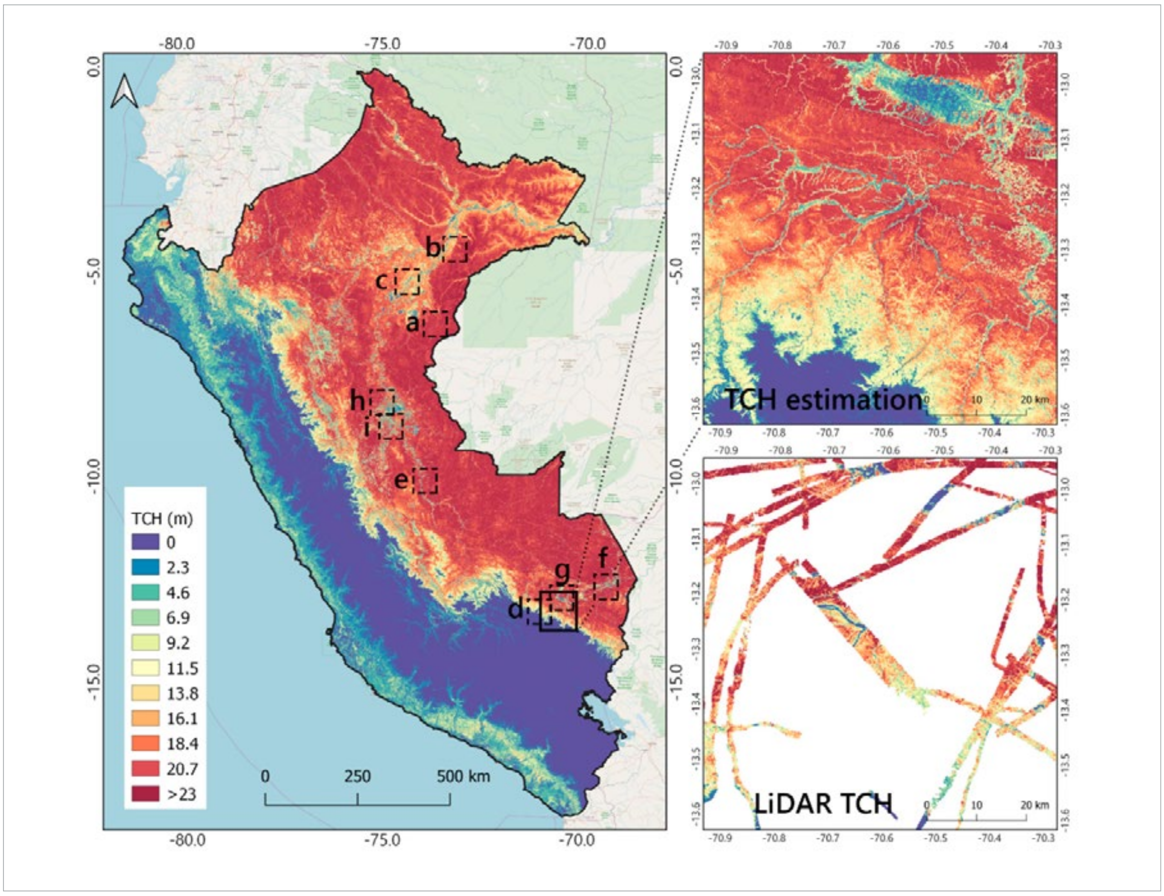
Cannistra et al. (2021) used a convolutional neural network, trained with PlanetScope 3 m resolution data to map snow cover in the Sierra Nevada and Rocky Mountains in the U.S. The PlanetScope model showed comparable performance to models based on Sentinel-2 or Landsat imagery, but operational at 3 m spatial resolution. Further details in Cannistra et al. (2021).

4/BIOSPHERE

Earth is the only planet known to harbor life. And now, Earth has entered the "Anthropocene" — a new geological epoch defined by the enormous reach of humanity over the biosphere. Humans now directly occupy or control the fundamental ecological processes of roughly 50 percent of the Earth's land surface, and have a pervasive and poorly quantified influence on the oceans. Humanity has altered nearly all of our planet's biogeochemical cycles, even in the most remote ecosystems. Planet's high-resolution and dense time series data provide a unique opportunity to monitor and mitigate these threats.

CZU Complex Fire, Santa Cruz, California
August 20, 2020

Carbon Stocks & Emissions



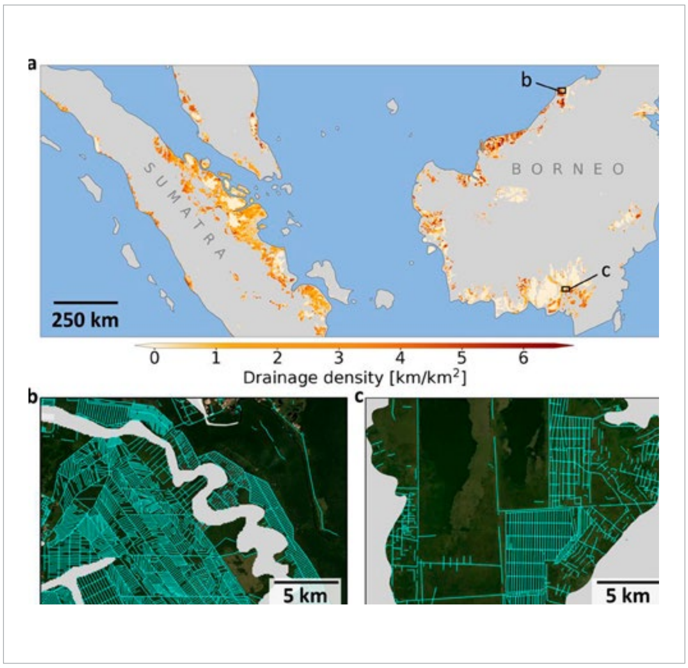
Csillik et al. (2020) used a combination of field data, airborne LiDAR, and Planet imagery to generate 1-ha resolution carbon stocks and emissions estimates for Peru.

Satellite imagery has been used to estimate forest area change for decades. In the past, because available satellite imagery over large areas was low resolution and infrequently updated, details on the ground like forest degradation or fast-moving land conversion were often missed. Moreover, although map forest cover mapping was possible, only indirect estimates of the corresponding forest carbon stocks and emissions could be made.

In the past, scientists have used airborne Light Detection and Ranging (LiDAR) to estimate the amount of carbon that tropical forests were storing, but it has traditionally been difficult to implement this process at scale or high-frequency due to cost.

However, new breakthrough research from Arizona State University's (ASU) Center for Global Discovery and Conservation Science helps to remove these technological and cost barriers, using machine learning to combine the insights of ASU's Global Airborne Observatory LiDAR with Planet's high spatial and temporal resolution satellite imagery (Csillik et al. 2019, 2020). Focusing their efforts on Peru, Csillik's team trained and tested their machine learning models using extensive sampling of forest carbon estimates from their Global Airborne Observatory's in-country flight campaigns. The models then ingested Planet's analysis-ready basemaps and other auxiliary data to comprehensively measure aboveground carbon of every hectare in Peru.

Tropical peatlands are also under threat as agricultural activity expands. When water levels in peatlands decline, carbon is released into the atmosphere. The extent of construction of drainage canals constructed to dry out peatland soils for agricultural use is poorly documented. Using PlanetScope imagery and machine learning, a multinational group out of the U.S., Germany, Switzerland, and Singapore led by Nathan Dadap (2021) created the first regional map of these canals in Southeast Asia. They found that at least 65% of Southeast Asian peatlands are being drained at present, leading to widespread carbon emissions, but also ground subsidence when analyzing PlanetScope alongside ALOS-1 radar data. According to the study authors, their maps of subsidence from these emissions can be used to "target areas for hydrologic restoration."



Drainage canals mapped using PlanetScope data by Dadap et al. (2021)

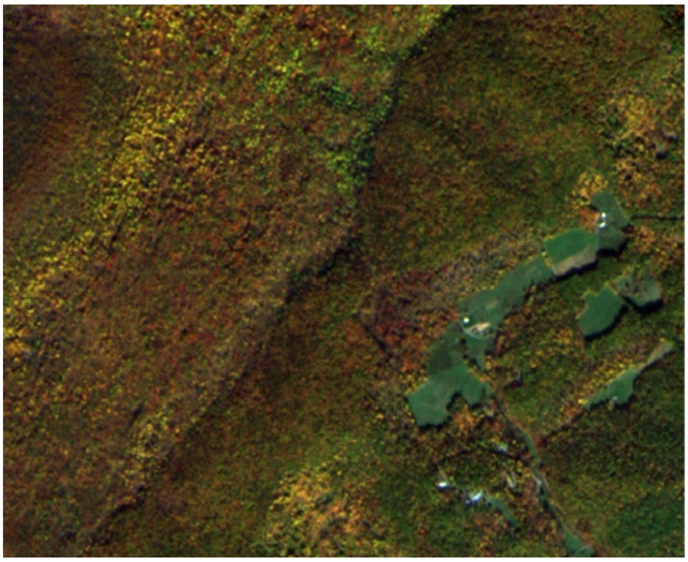
Forest Phenology

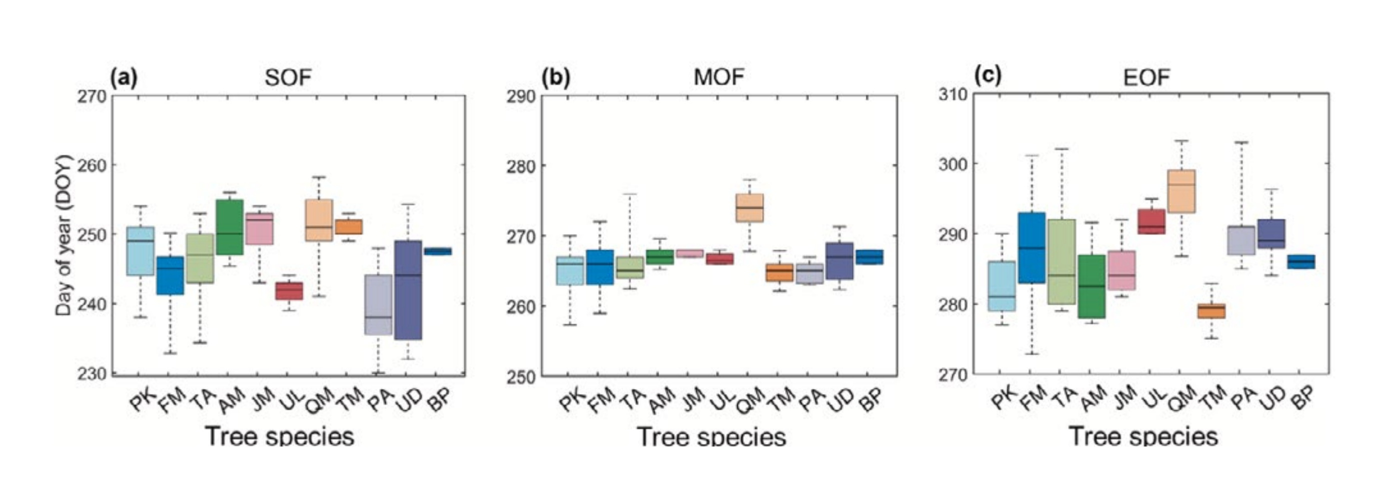
Professor Jin Wu and his team at the University of Hong Kong study tropical and temperate forest phenology — the rhythms and periods of life.

Aided by the high revisit rate of Dove satellites, Wang et al. (2020) detected dry season vegetation patterns in the Amazon: many tropical trees are deciduous, dropping all or some of their leaves in the dry season, then flushing new young growth in bursts. The causes and consequences of these patterns remain poorly understood, but have enormous implications for forest ecology and the relationships between forests and climate. Wang et al. used MODIS data fused with Planet imagery to explore fine variations in dry season green up (flushing) and brown down (leaf loss).

Building on this methodology, Wu et al. (2021) used similar phenological tracing — in this case, in temperate forests in Northern China. Wu and colleagues were able to detect the autumn color changes at the level of individual tree canopies, allowing them to isolate particular tree species, including oaks, hickories, basswoods, elms, and others. These methods have the potential to dramatically improve biodiversity mapping with satellite imagery.

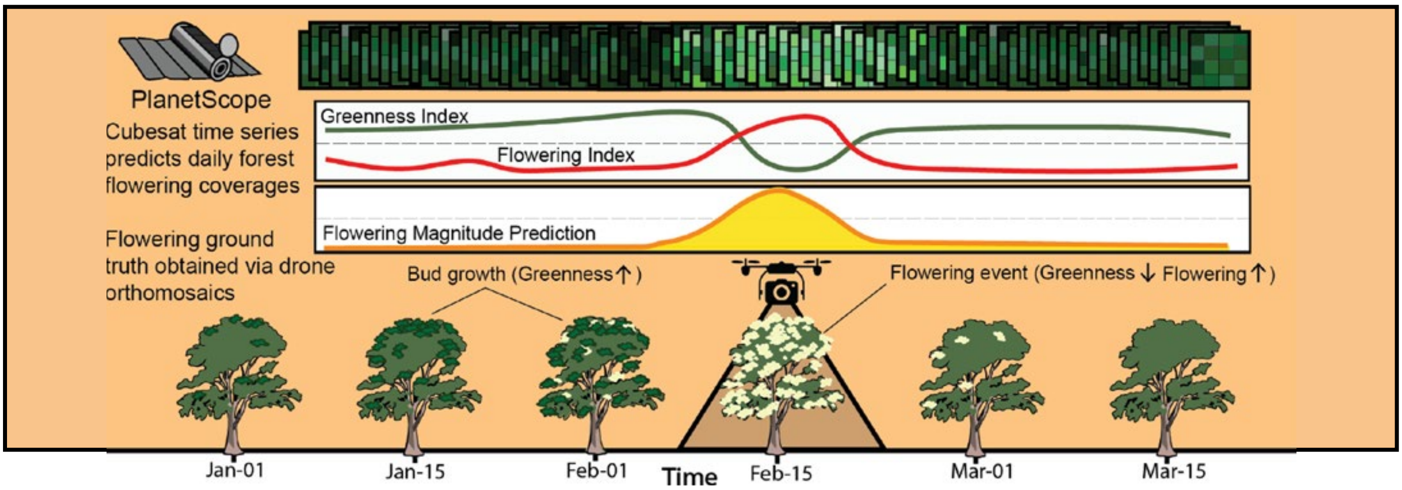
Dove satellite images capture the high-frequency changes in autumn colors in temperate forests in Pennsylvania (October, 2020).





Wu et al. (2021) used PlanetScope data to detect phenological changes in temperate tree species in China, and subsequently classify those species' canopies based on the arrival of the start of fall (SOF), middle of fall (MOF) and end of fall (EOF). Further details in Wu et al. (2021).

Flowering Events



Visualization of the detection of flowering events using PlanetScope from Dixon et al. (2019)

A team at the University of Western Australia led by Dan Dixon used Planet data in combination with drone observations to peer into one of the most poorly understood aspects of forests: flowering. With 3.7 m spatial resolution, Planet's Doves are among the few satellites that can detect flowering on tree canopies from space. Dixon et al. (2021) used spectral indices to distinguish green vegetation from cream-colored flowers on the eucalypt Corymbia calophylla in PlanetScope imagery. Combining PlanetScope with high-resolution drone imagery, they were able to create a machine learning model that can accurately predict pixel-level flowering events throughout the flowering season. Dixon et al. report that **"Due to the spatiotemporal coverage of satellite images, this model can be deployed to generate regional maps of flowering dynamics in forest ecosystems that can be used for monitoring forest ecosystem condition and supporting research into drivers of eucalypt forest phenology."**

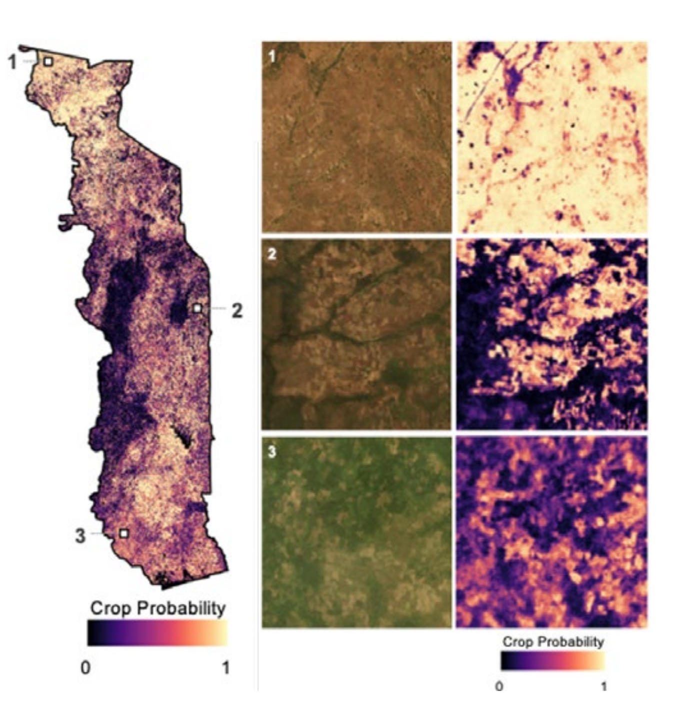
Wildfires

Satellite imagery has played an important role in better analysis of wildfire burned area, helping understand fire extent. Mapping such damage is essential for fire management groups for planning, forest health assessments, and future carbon budgeting. As such, there is a growing demand for medium/high resolution burn area products. Roy et al. (2019) created a combined multi-sensor approach to evaluate burn area analysis. Using a Random Forest algorithm, they were able to fuse Landsat 8, and Sentinel-2 data to a 30 m twice-weekly solution. This fusion methodology was compared against the daily 500 m resolution data from MODIS, and near-daily PlanetScope data. Roy et al.'s method typically detected burned areas three days after the initial wildfire detection by MODIS. They found that Planet's temporal and spatial resolution enables researchers to better understand the small scale differences between unburned and burned areas.

PlanetScope view of August 2016 burn scars in one of the focus areas of Roy et al. (2019) in Zambia.

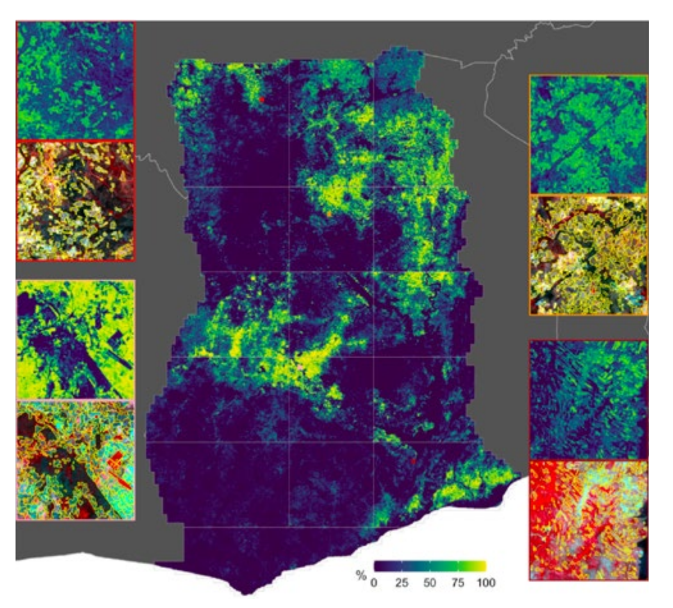
Food Security

Spatial information on cropland distribution is a critical input for a wide range of agriculture and food security analyses and decisions. However, up-to-date high-resolution cropland maps are not readily available for most countries, especially in regions dominated by smallholder farming (e.g., sub-Saharan Africa). During the COVID-19 pandemic, smallholder farms were at great risk due to supply chain shutdowns. Looking to distribute aid to farmers to boost food production and ensure food security, the government of Togo enlisted the help of NASA Harvest, NASA's Food Security and Agriculture program run out of the University of Maryland that consists of a consortium of academic, government, and industry partners. Planet is a proud member of the consortium. Working with Planet, a NASA Harvest team led by Dr. Hannah Kerner was able to produce a country-wide cropland map and deliver it to the Togolese government in only 10 days using machine learning with a combination of PlanetScope, SkySat, and Sentinel-2 data. This demonstrated a successful transition of machine learning applications research to operational rapid response in a real humanitarian crisis.



Cropland probability map generated by Kerner et al. (2020) for the country of Togo. RGB color subsets of the SkySat Basemap used are displayed alongside the resulting machine learning mapping results.

In nearby Ghana, Estes et al. (2021) used PlanetScope data to produce a complete cropland map of the country. Estes et al. ingested millions of square kilometers of PlanetScope data to generate two composites for the wet and dry seasons, and built a labelling platform together with an active learning process to generate cropland probability. Estes et al. report that "These results demonstrate a readily adapted, transferrable framework for developing high resolution, annual, nation-scale maps that provide important details about small-holder-dominated croplands."



Estes et al. (2021) mapped all agricultural systems in Ghana using a Random Forest machine learning approach that ingested millions of square kilometers of PlanetScope data. The map is one of the highest resolution maps of agricultural footprint in a large small-holder dominated nation. Percent cropland is shown in the center, with zooms highlighting field boundaries as detected by the machine learning approach. Further details in Estes et al. (2021).

Such smallholder agriculture mapping tools can improve humanity's ability to adapt to changing agricultural conditions with climate change and other human modifications of the Earth system.

5/ATMOSPHERE

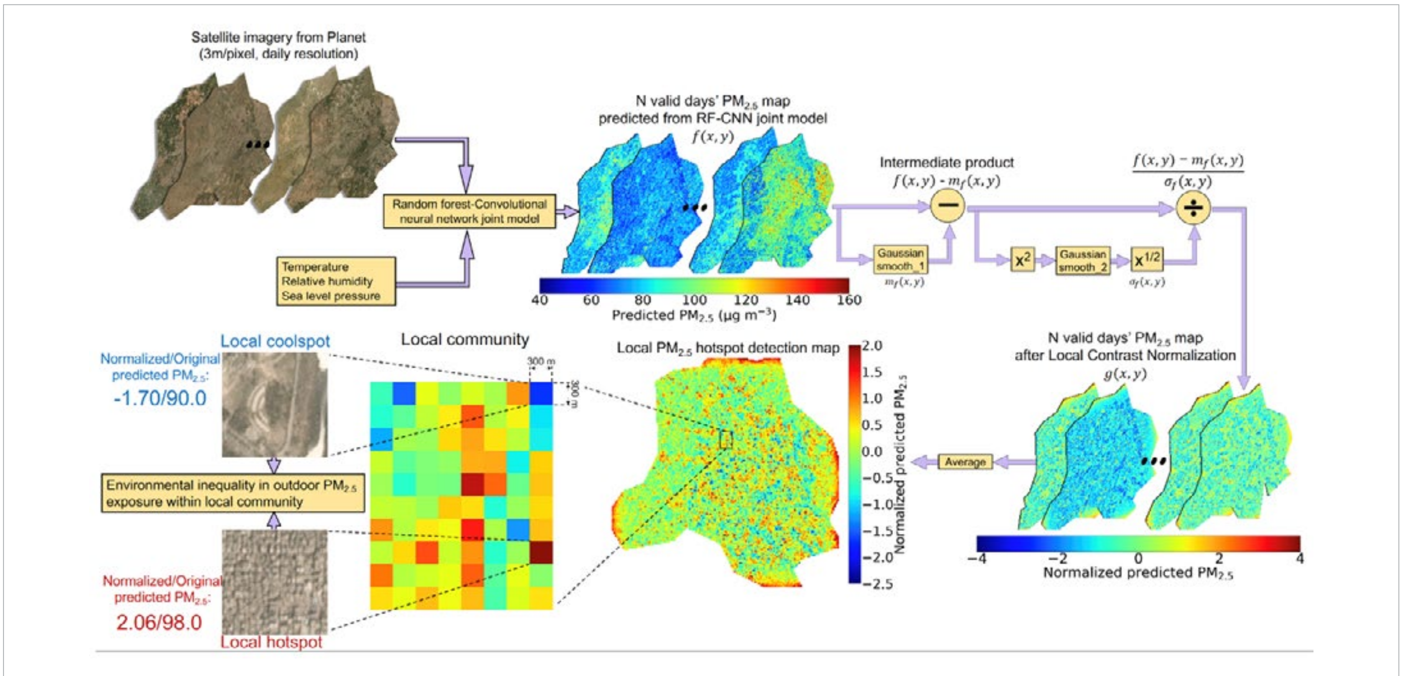
Air quality dramatically impacts human health globally. Remote sensing methodologies can effectively track changes in air quality using a myriad of sensors that can help researchers better understand pollutant sources and distribution over time.

Rio Purus, Brazil
July 21, 2015

Particulate Matter

There is a high demand for localized, fine-scale information on $PM_{2.5}$ air pollution. Satellite imagery has the potential to play an important role in tracking thesepollutants, which pose a serious human health risk.Zheng et al. (2021) used a pipeline of Random Forest, a deep convolutional neural network, and local contrast normalization to generate daily 300 m ground level $PM_{2.5}$ estimates. This methodology can help identify local $PM_{2.5}$ hotspots and track variations over time. They focused on Beijing and Delhi, two of cities with the world's highest concentrations of $PM_{2.5}$. The study highlights local $PM_{2.5}$ hotspots in dense urban areas, and lower concentrations in open, rural areas. This methodology uses the visual appearance of features such as buildings as a proxy for haziness in the images combined with information on meteorological conditions in the metadata to track $PM_{2.5}$ levels.

The application of these methodologies can help cities with poor air quality globally to develop a better understanding of air pollution hotspots. Understanding where these hotspots are will help to determine large point source polluters in the area. This can help cities create more informed policies to support localized air quality standards.

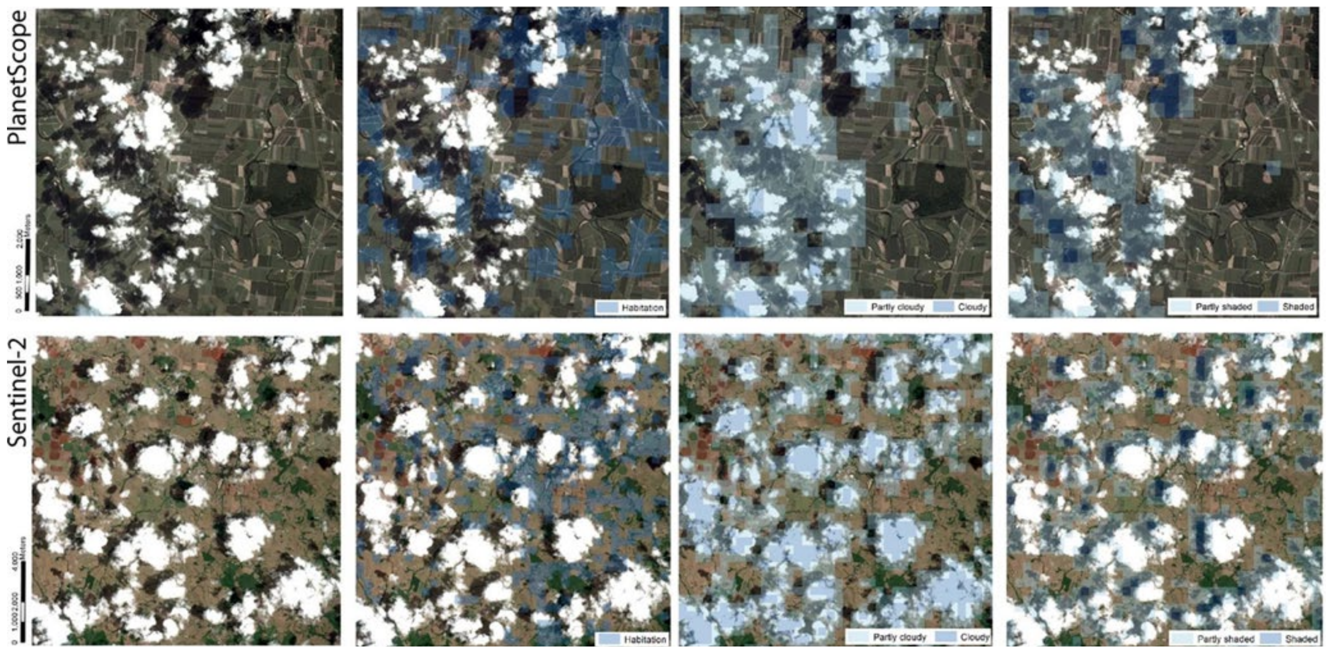


Zheng et al. (2021) used near-daily PlanetScope data to create a PM2.5 hotspot detection map of Delhi, India.

Cloud Masking

The growing availability of high-resolution satellite imagery has led to greater demand for rapid and robust indexing, retrieval, and feature classification. This is of particular interest to support land use classification and change detection irrespective of any differences in spatial, spectral, temporal and radiometric resolutions across satellite data sources.

Researchers from the Commonwealth Scientific and Industrial Research Organisation (CSIRO), an Australian Government agency responsible for scientific research, developed cloud and cloud shadow masking algorithms using Convolutional Neural Nets (CNN; Shendryk et al. 2019). Utilizing PlanetScope and Sentinel-2 imagery over the Amazon and Wet Tropics of Australia, the CNN enabled the group to perform "multi-label classification of multi-modal, high-resolution satellite imagery at the scene level." Typically indexing is done at the pixel level, which can be a time-consuming task. The ability to do indexing at the scene level allows for faster performance, as well as higher accuracy. Their results suggest that these models have high generalization ability, and are well suited for cloud, shadow, and land cover classification.



Examples of feature classification results using a CNN on PlanetScope and Sentinel-2 images over the Wet Tropics of Australia from Shendryk et al. (2019).

6/GEOSPHERE

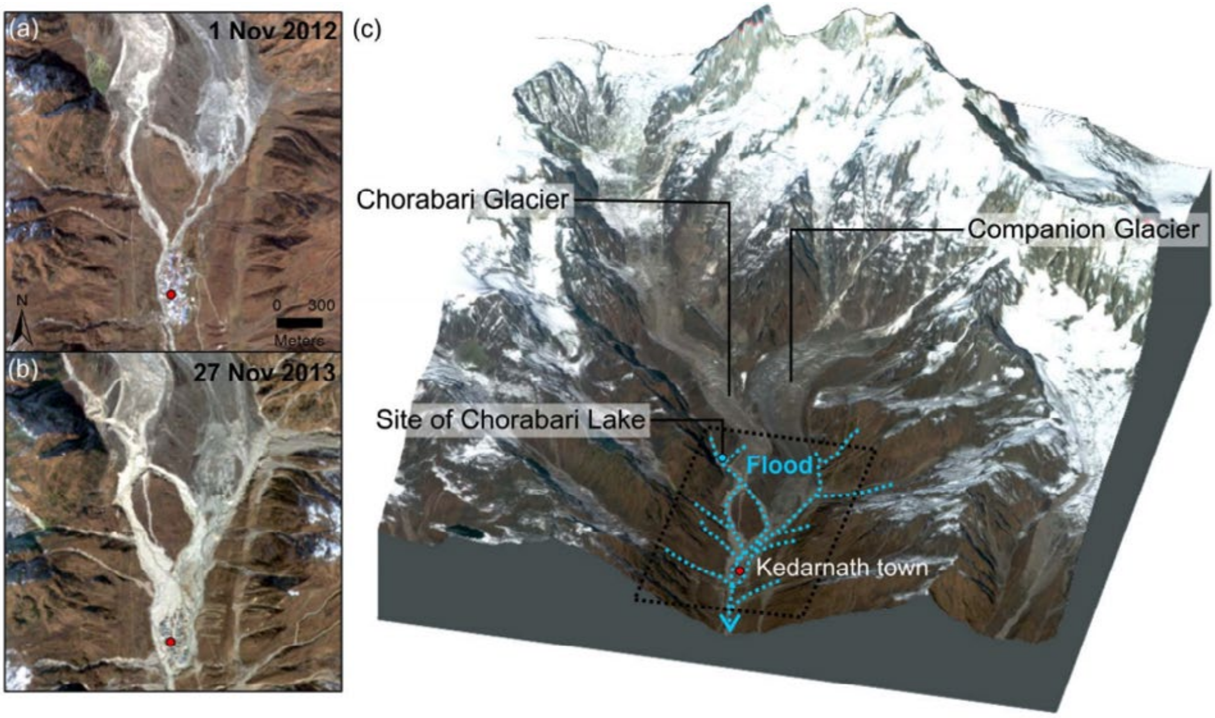
Many communities live in mountainous or glaciated terrain, with a constant threat of landslides and avalanches. Remote sensing methods, including construction of digital elevation models (DEMs), have the potential to detect deformation of the Earth's surface and give early warning signals of impending hazards.

Gjerdrum Landslide, Ask, Norway
January 4, 2021

Landslides

The towering mountain ranges of the Tibetan Plateau, such as the Himalayas and the Hindu Kush, are a prime area for a host of natural disasters. Earthquakes, landslides, and glacial floods are common occurrences in the region thanks to the confluence of geological activity there, along with the effects of climate change. However, the remote location and rough terrain makes it difficult to access. But remote sensing datasets like those from Planet's SkySat, PlanetScope, and RapidEye are bringing revolutionary views of these areas. A research group led by Dr. Dalia Kirschbaum out of NASA Goddard Space Flight Center analyzed a range of satellite datasets to see how they could benefit natural hazard assessment within High Mountain Asia, looking at the complex interplay between humans, infrastructure, and ecosystems.

The study found that the short revisit time of PlanetScope aided in detecting early warning signs for natural disasters in the region. This includes the ability to look for precursors to landslides, and to monitor surface velocities of glaciers as a sign of impending surges that can precede catastrophic floods. They also found PlanetScope data "essential"in reconstructing the sequence of events post-disaster thanks to both image resolution and rapid revisit rates.



Aerial view of Kedarnath town with (a) pre and (b) post-event RapidEye imagery from November 1, 2012 and November 13, 2013. (c) Shows a broader view of the source areas, location of the Chorabari Lake, and direction of flooding associated with the Kedarnath debris flow (right). From Kirschbaum et al. (2019).

Earthquakes

On September 28, 2018, a destructive magnitude 7.5 earthquake struck central Sulawesi, Indonesia. The strength and stiffness of the soil decreased dramatically due to the shaking of the great quake, turning it from a solid to a liquid in one of the most dramatic soil liquefaction events ever recorded, leading to destructive landslides. Without the support of intact soil, buildings and structures were overturned or reduced to rubble, contributing significantly to the death toll of over 4,000 people.

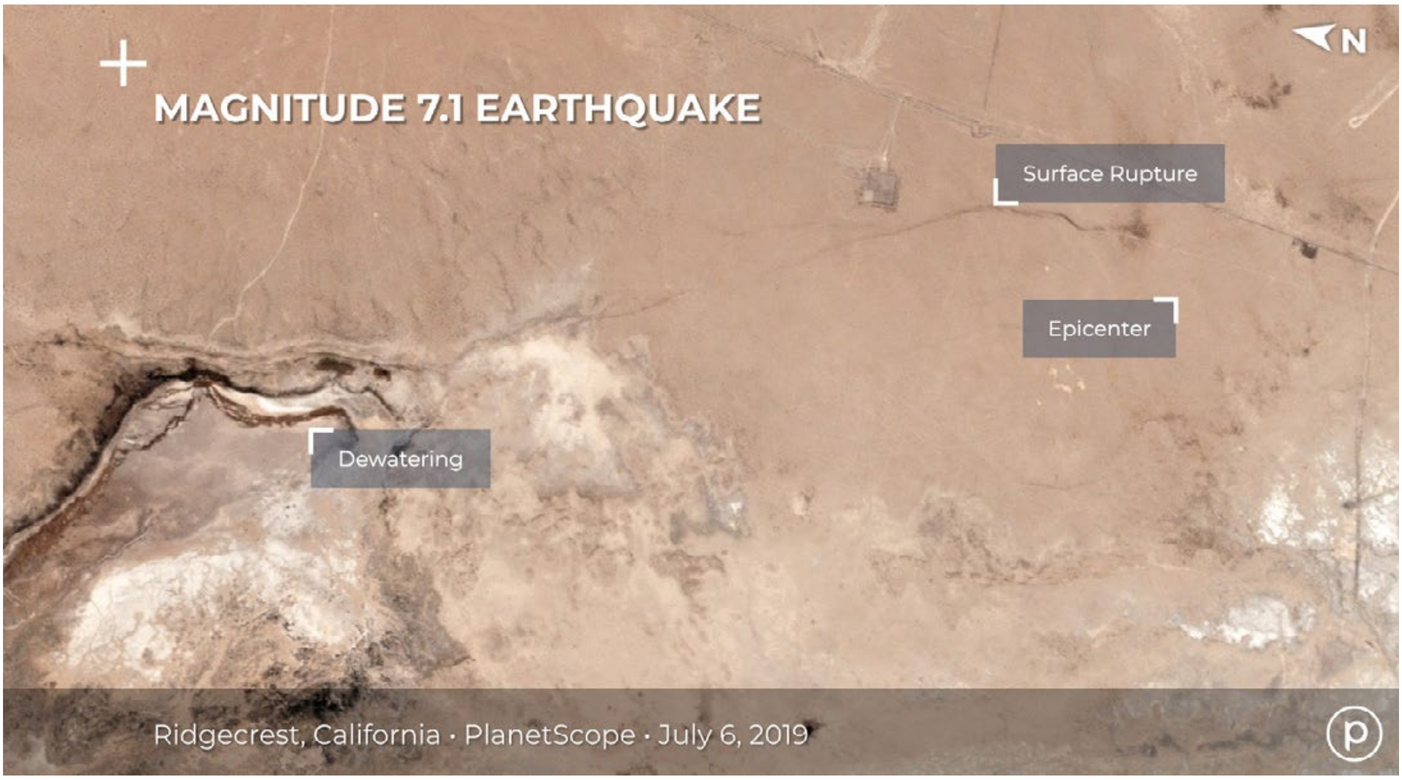
In an effort to better understand the unexpected severity of landslides triggered by the earthquake, a multinational research team spanning four continents, led by Dr. Kyle Bradley at the Earth Observatory of Singapore, utilized daily PlanetScope imagery to map out surface ruptures and landslides. The team discovered that the ground failure and landsliding in the Palu Valley was largely the result of irrigated rice paddies sitting atop alluvial fans. “We were able to use PlanetScope images captured directly before and after the earthquake, which allowed us to focus on and isolate the landsliding caused by ground shaking,” Bradley explains.

In the study, Bradley’s team highlights the need for more proactive assessment of the potential hazards caused by farming and irrigation. Alluvial fans had not previously been considered a threat, as soil liquefaction of this magnitude in this type of material had never been observed before. “Earthquake-triggered landsliding of gentle, irrigated alluvial slopes is an under-recognized, but avoidable, anthropogenic hazard,” the researchers note in their paper.

PlanetScope view of sediment flowing through the Palu River as a result of the September 28, 2018 Mw7.5 earthquake.

Monitoring changes to the dangerous San Andreas faultline is of critical importance in California. The Eastern California Shear zone is an active fault that continues to move. The 2019 Ridgecrest earthquake caused cascading ruptures in the Eastern California shear zone. A M_w6.5 earthquake, followed shortly after by a M_w7.1 earthquake, struck Searles, California on July 4–5, 2019. Researchers from California Institute of Technology implemented an innovative methodology to generate DEMs using PlanetScope to understand the surface deformation from these two seismic events.

With the help of COSI-CORR, Milliner and Donnellan (2020) were able to generate DEMs from Planet Scope data. By mapping the fault trace for each quake, they found that the initial M_w6.5 triggered the secondary M_w7.1 earthquake. The first quake "initiated on a right-lateral NW striking fault and then ruptured a left-lateral fault to the surface. This event triggered a right-lateral slip during the M_w7.1 earthquake."



PlanetScope view of a surface rupture and dewatering from the M_w7.1 earthquake discussed by Milliner and Donnellan (2020).

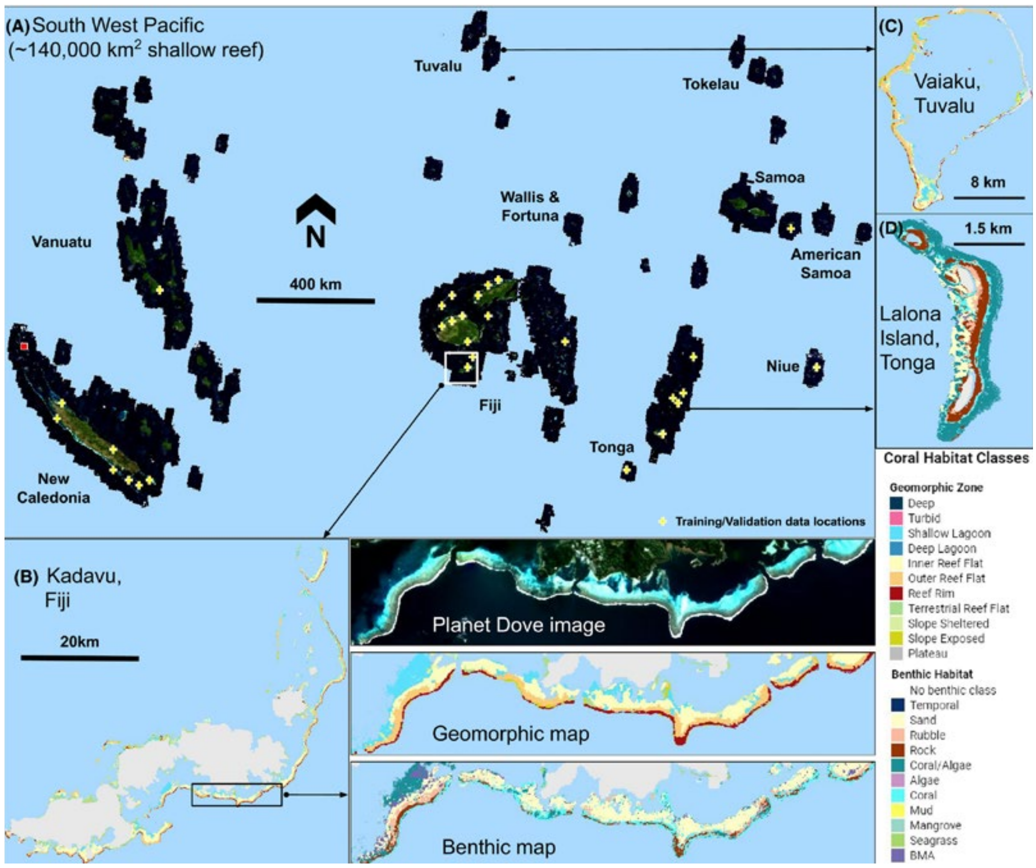
7/HYDROSPHERE

Near-shore marine environments, including coral reefs, mangroves and seagrass beds, play a critical role in ocean ecosystem functioning, and provide habitat for a vast portion of marine wildlife. Because these ecosystems are so dynamic and are exposed to a variety of stressors including climate change, storms and human-caused modification, monitoring their change over time is of critical importance.

West Coast of Grande Terre, New Caledonia, France
May 21, 2020

Coral Reefs

The Allen Coral Atlas created a map of the world's shallow coral reef systems using satellite and in situ data. Coral reefs are highly vulnerable to the impacts of climate change, and therefore monitoring how they change over time is critical to their preservation. Satellite data is the only viable method for large-scale monitoring as many reef systems are extremely remote, and therefore both difficult and expensive to access. A multinational team of researchers led by Mitchell Lyons at the University of Queensland contributed to the atlas by creating a framework for mapping reefs from the individual to oceanic scale. Their methodology combines the power of image segmentation, machine learning, and object-based classification with PlanetScope and other satellite imagery. Creating ten different maps, their approach provided a mean overall accuracy of 78%. "An agile mapping framework such as ours offers an opportunity for investment from management agencies or conservation organizations, to provide data for their own application, as well as continue to improve input data and validation procedures," Lyons et al. (2020) remark in their paper.

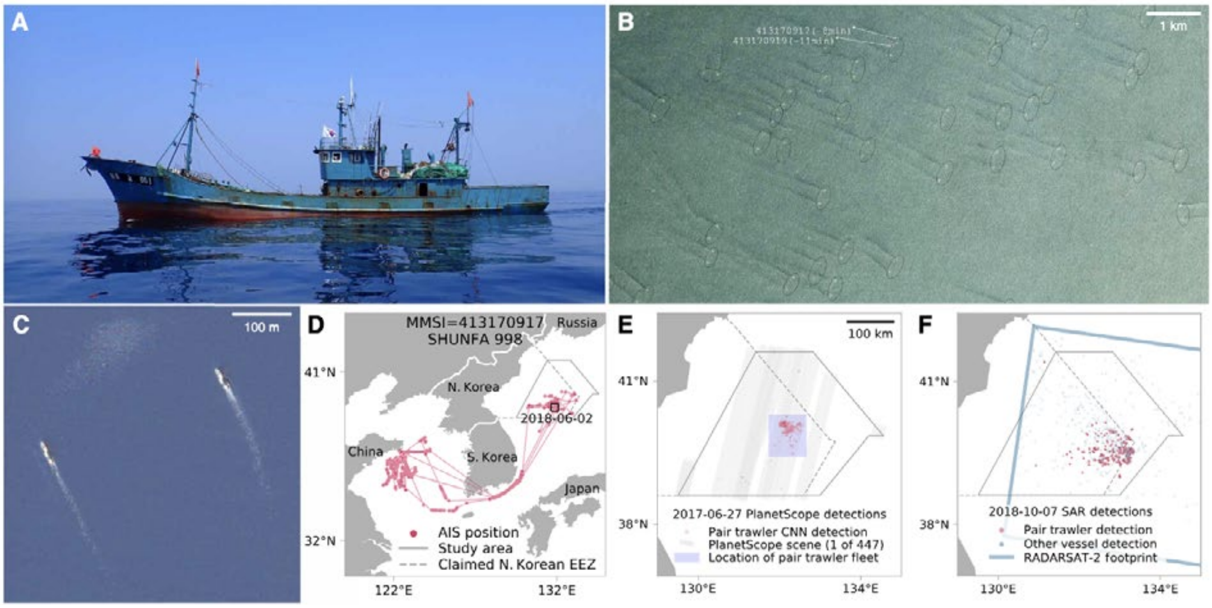


Example of the varying spatial scale and detail possible using PlanetScope for coral reef mapping across Fiji, Tuvalu and Tonga from Lyons et al. (2020). The maps can be explored in detail here: mitchest.users.earthengine.app/view/coral-map-explorer.

Catching Illegal Fishing

Researchers at Global Fishing Watch utilized Planet's Dove and SkySat imagery, in concert with other innovative technologies, to reveal widespread illegal fishing in the waters between the Koreas, Japan and Russia. Park et al. (2020) showed the value of satellite imagery for exposing "dark fleets" — fishing vessels that don't broadcast their locations in public monitoring systems — which can take part in illegal, unreported, and unregulated fishing practices.

The study found more than 900 vessels of Chinese origin in 2017, and 700 in 2018, likely violated United Nations (UN) sanctions by fishing in North Korean waters. It is estimated that the vessels likely caught more than 160,000 metric tons of Pacific flying squid, worth over $440 million. Unidentified vessels create issues for squid stock management, according to the study, as the number of reported catches has dropped by about 80 percent since 2003. The research also revealed that approximately 3,000 North Korean vessels participated in illegal fishing in Russian waters in 2018.



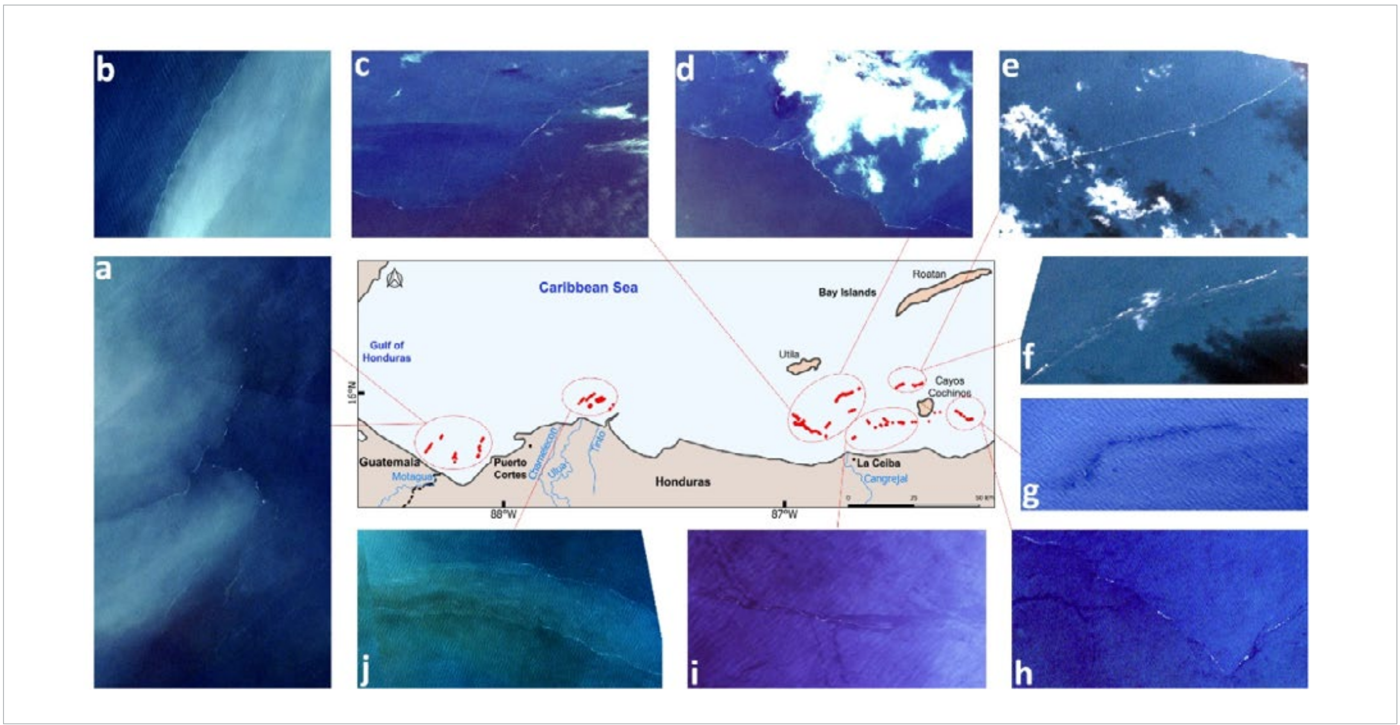
Park et al. (2020) tracked illegal fishing activity from a pair of trawlers from China in North Korean waters using PlanetScope (B) and SkySat (C) imagery from 2017–2018.

"The scale of the fleet involved in this illegal fishing is about one-third the size of China's entire distant water fishing fleet. It is the largest known case of illegal fishing perpetrated by vessels originating from one country operating in another nation's waters," said Jaeyoon Park, senior data scientist at Global Fishing Watch and lead author of the study. "By synthesizing data from multiple satellite sensors, we created an unprecedented, robust picture of fishing activity in a notoriously opaque region."

As relevant governments investigate any breach of the UN sanctions banning fishing activity in North Korean waters by other UN Member States, satellite data can support nations who seek to increase their monitoring efforts — especially those who have limited resources for controlling illegal fishing across waters can greatly benefit countries committed to stamping out illegal fishing and enhancing monitoring efforts; and can serve to support nations with limited capacity and resources to control fishing activity in their waters.

Tracking Marine Plastic

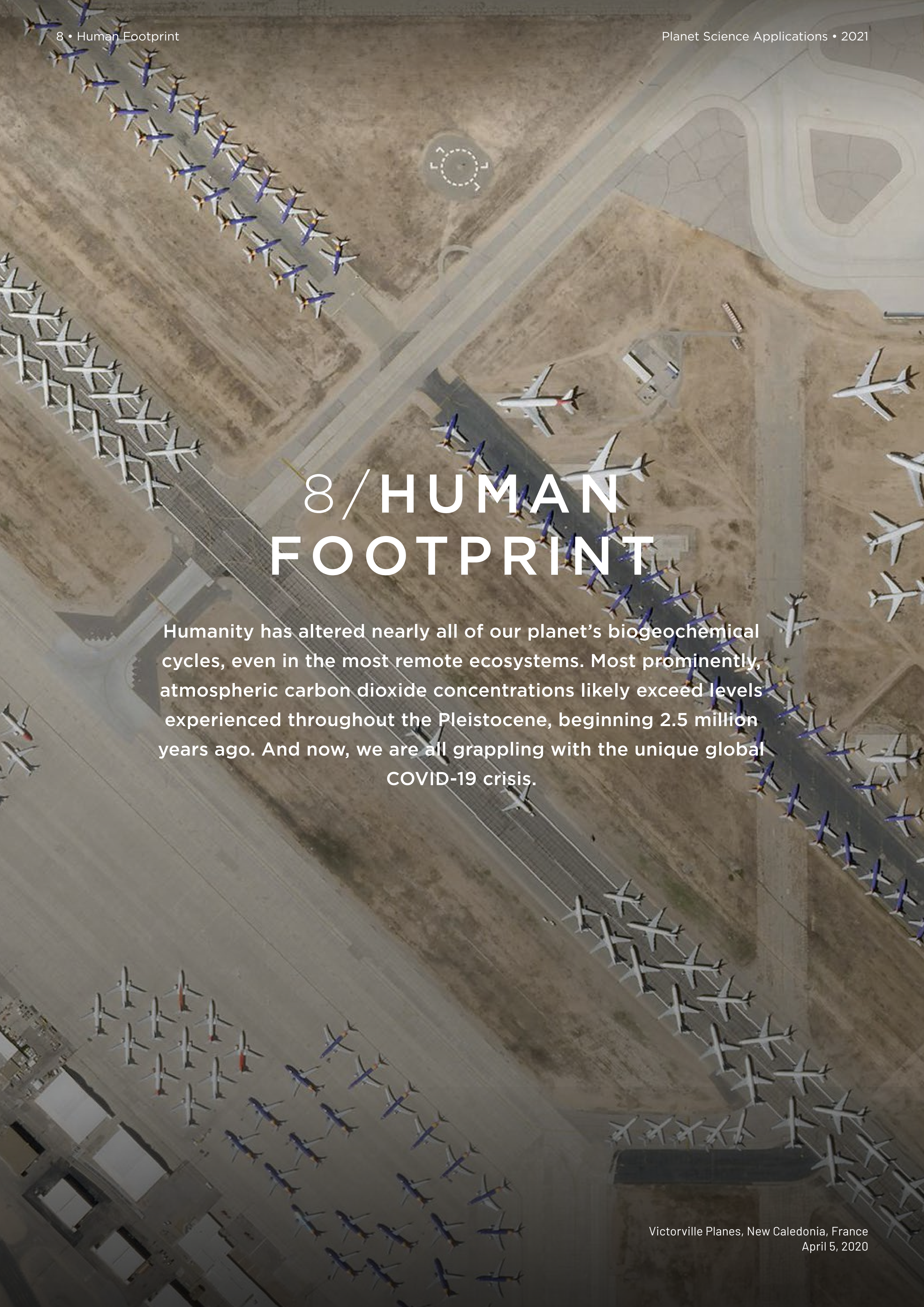
One of the most pressing problems in marine pollution is microplastic debris, with an estimated 93,000 to 236,000 metric tons of microplastic in our oceans as of 2014. Over the past 60 years, the accumulation of plastic debris has led to the formation of garbage patches — massive gyres of non-biodegradable plastic — and tons of microplastic seafloor sedimentation across global seawaters. Plastics are found not just in the ocean, but in different trophic levels of the marine ecosystem, including over 50 percent of the fish species found in the American and Indonesian markets.



Kikaki et al. (2020) used PlanetScope (a–f; g–i) and Sentinel-2 (g) imagery from a period of the major rainfall season in September–October 2017 to look for debris trails at the Gulf of Honduras and Bay Islands.

In order to investigate the capability of satellite imagery in detecting marine plastic debris, Kikai et al. (2020) utilized Planet data in a five-year study observing the Bay Islands and Gulf of Honduras. This was the first-ever study to only detect, but also track and map out plastic debris movement using high-resolution multispectral satellite imagery coupled with verification from in-situ observations.

"While other studies have used remote sensing to identify plastic debris, our study dynamically tracks its movement, and can open up new doors for marine pollution monitoring and safeguarding our oceans," says co-author Konstantinos Karantzalos, associate professor at the National Technical University of Athens. This study not only shows how satellite remote sensing is an efficient and cost-effective tool for monitoring plastic debris, but it also demonstrates the value of integrating satellite information into future ocean clean-up and protection efforts.



8/HUMAN FOOTPRINT

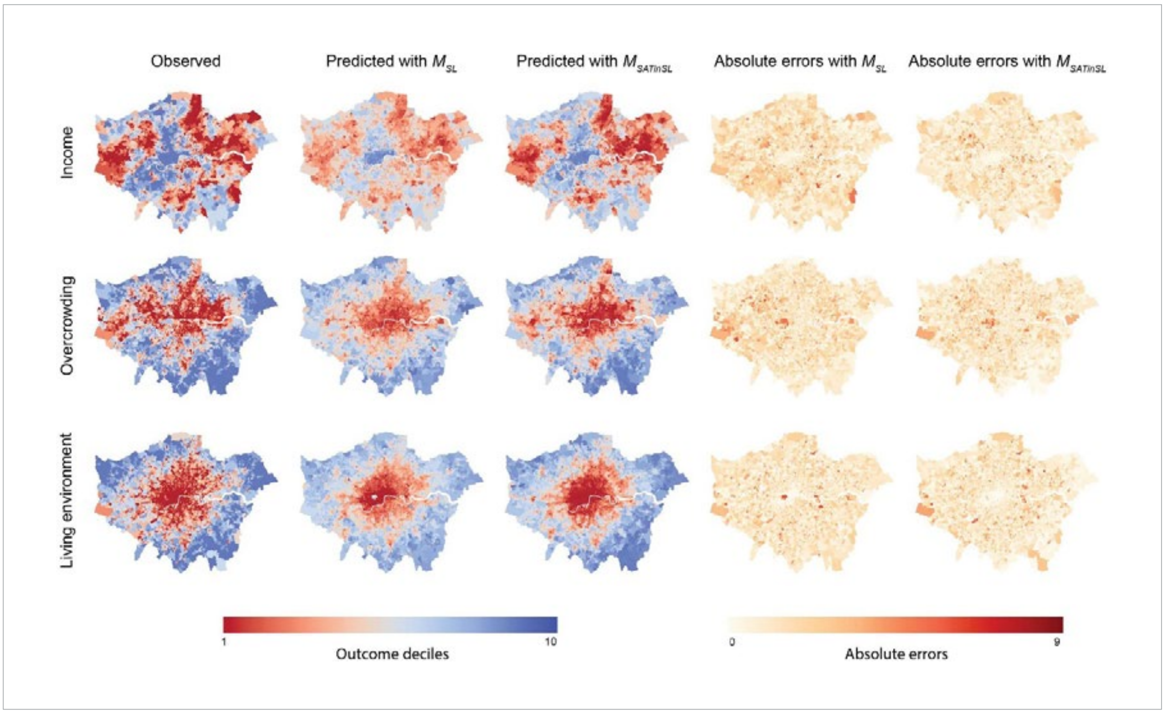
Humanity has altered nearly all of our planet's biogeochemical cycles, even in the most remote ecosystems. Most prominently, atmospheric carbon dioxide concentrations likely exceed levels experienced throughout the Pleistocene, beginning 2.5 million years ago. And now, we are all grappling with the unique global COVID-19 crisis.

Victorville Planes, New Caledonia, France
April 5, 2020

Overcrowding & Urban Income Distribution

Planet's spatiotemporal resolution plays a relevant role in understanding socioeconomic trends. Over 50% of the global population resides within urban areas. The continued growth of urban areas will lead to new socioeconomic challenges such as adequate and affordable housing and healthcare access. A group of researchers from the Imperial College (Suel et al. 2021) created a methodology that integrates Planet imagery, street level imagery, and census data from London to predict income, overcrowding, and environmental deprivation.

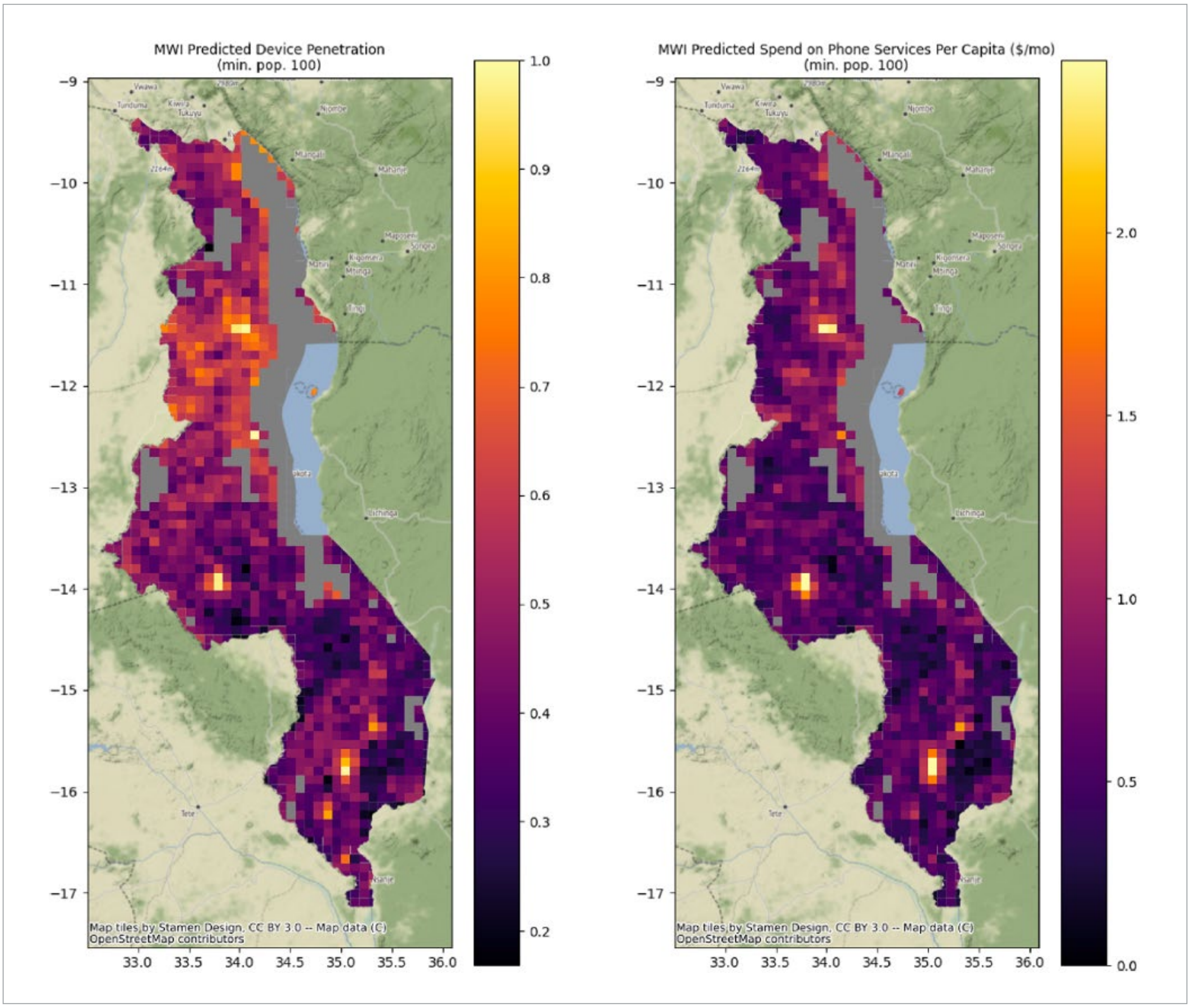
The researchers used machine learning to track income, overcrowding, and living environmental deprivation. Planet data specifically helped with tracking overcrowding and living environmental deprivation factors. Their methodology "successfully utilized different information from multimodal imagery data, i.e., street-level and satellite images, and outperformed measurement performances obtained from unimodal alternatives in our experiments," Suel and team state in their study.



Comparison of ground truth and prediction maps generated by models. From Suel et al. (2021).

Mapping Phone Usage Patterns

Governments and mobile network operators struggle to determine if infrastructure investments are viable in developing regions where demand is unknown. Oughton and Mathur (2021) used PlanetScope combined with World Bank surveys across Ethiopia and Malawi looking at cell phone use, fed into a convolutional neural network. Both countries lack comprehensive mobile broadband coverage, but each represents a different economic setting: Ethiopia has the fastest growing economy in the region, while Malawi is one of the poorest countries in the world. Therefore, looking at both countries provided a good way to compare their model results. From their machine learning approach, they were able to create 10x10 km resolution country-wide maps of predicted cellular device penetration and predicted spend on phone services per capita. **These maps can be used by governments and corporations to better inform policy decisions and infrastructure investments.**

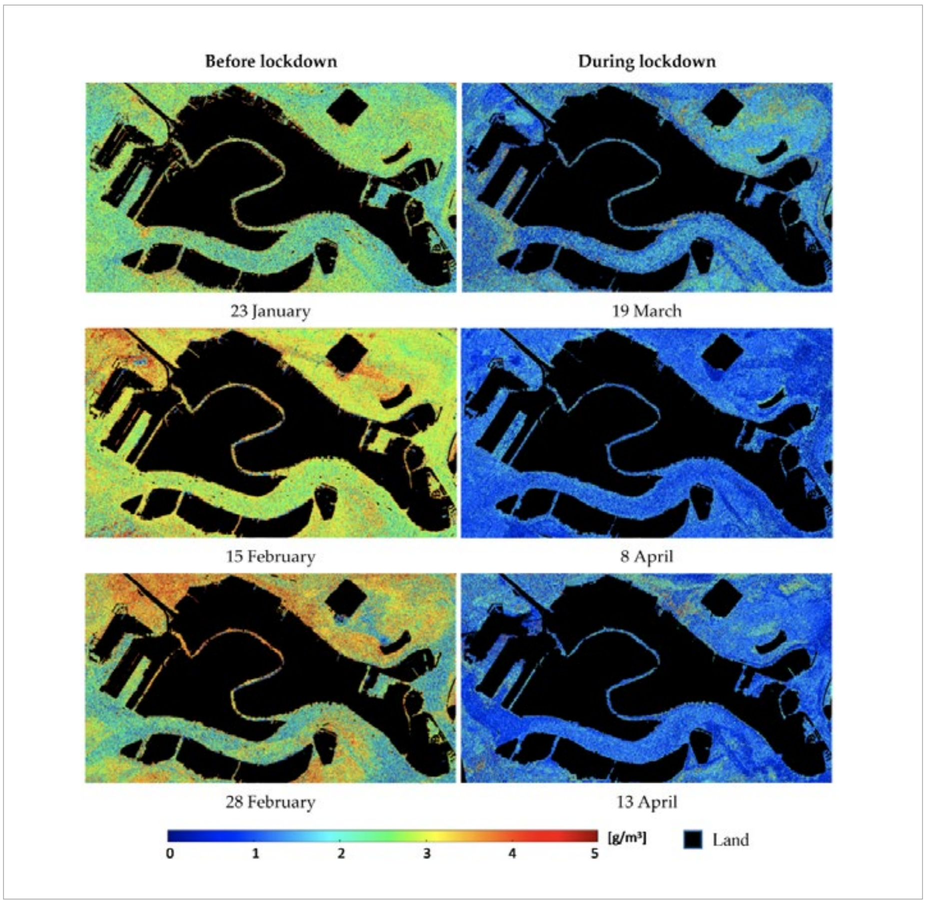


Oughton and Mathur (2021) used PlanetScope and World Bank surveys across Ethiopia and Malawi looking at cell phone use to create predictive maps of cellular device penetration and phone service spend per capita, which can help in policy and infrastructure investment decision-making efforts.

Effects of Covid-19 Lockdowns

Early in the COVID-19 pandemic, the effects of lockdowns on the Earth system were clearly visible from orbit, including vacant highways, and reductions in air pollution. People affected in Venice reported that the local waters were clearer than they'd seen in decades. Niroumand-Jadidi et al. (2020) used PlanetScope imagery to measure the effects of the lockdown on Venice waters, as well as a flood that occurred just before the pandemic. They report "a remarkable reduction of the turbidity during the lockdown, due to the COVID-19 pandemic and capture the high values of TSM [total suspended matter] during the flood condition."

The authors further report that: "The high spatial resolution in combination with daily revisits of the PlanetScope constellation potentially enables advances in near real-time monitoring of inland/coastal aquatic systems. The meter-scale data offered by this constellation is of particular importance in studying small water bodies (e.g., narrow fluvial systems) where the spatial resolution of operational multispectral satellites such as Sentinel-2 and Landsat 8 (10−30 m) is not sufficient."



Maps of total suspended matter (TSM) in the Venice lagoon created using PlanetScope imagery by Niroumand-Jadidi et al. (2020), showing the striking difference before and during the COVID-19 lockdowns.

9/CLASSROOM OPPORTUNITIES

Planet's unique data and tools promote a deeper scientific understanding of the whole Earth system. In real time, students will witness infrastructure expand into natural ecosystems, respond to humanitarian crises, track glaciers receding, and devise new analytics to better understand and respond to these global challenges.

Eruption at Fagradalsfjall, Reykjanes Peninsula, Iceland
May 26, 2021

Example Course

Python for Geoscience

For students interested in private sector or government careers in geospatial data and tools, such a course provides an opportunity to target their Python training. For example, students may co-develop an earthquake monitoring and response tool, which would use the Planet API, combined with image processing and photogrammetry, to automatically analyze crustal deformation caused by an earthquake, generate shakemaps and build alerts.

Example Course

GIS

Planet will serve as an exemplar of very high spatial and temporal resolution data for GIS students, and also as a powerful data set for their course projects. We envision sourcing Planet data for lectures about scale, data sources, and the scene model, as well as a tool for Object Oriented Classification. By working with Planet data early in their GIS training, these students gain the advantage of becoming familiar with the future of remote sensing and will be better suited to apply their education in the field.

Example Course

AI for Earth Science

By applying machine learning techniques to Planet data, students will be on the cutting edge of innovation in remote sensing analytics. At Stanford University, for example, several students recently utilized Planet imagery in Computer Science 230: Deep Learning. Students examined deforestation near Kibale National Park in Southern Uganda, an incredibly diverse tropical forest, and home to a large chimpanzee population. The team used the “U-Net” algorithm, originally devised for biomedical image segmentation, to separate forest patches from surrounding non-forest habitat, producing a binary classification. They subsequently expanded their effort to parse forest density across multiple classes.

Inquire about Departmental or Campus Access

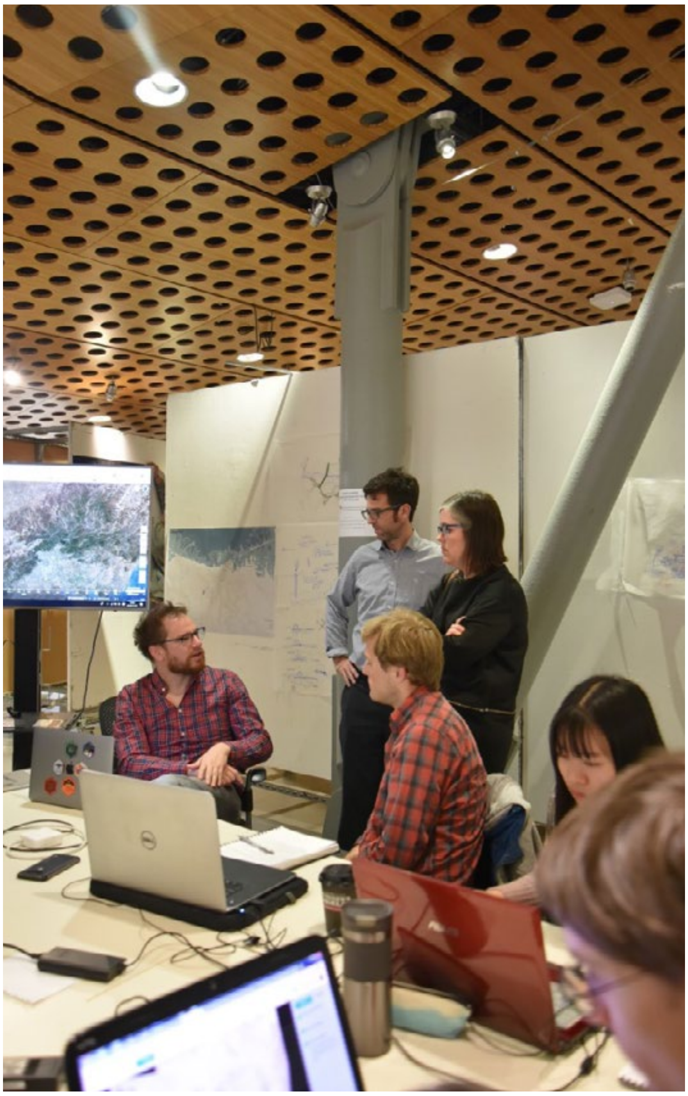
Planet's Education and Research program promotes a deeper scientific understanding of the whole Earth system. In real time, your students will witness infrastructure expand into natural ecosystems, respond to humanitarian crises, track glaciers receding, and devise new analytics to better understand and respond to these global challenges. Our Campus program is designed to provide access to Planet data across the entire university ecosystem: from undergraduates to postdocs, lecturers to research specialists.

"Planet data could be a great tool to introduce Object Oriented Classification, or even a great lecture about scale and data sources. Truly the options are endless!"

Ryan Frazier, Lecturer, Arizona State University

"For the first time, scientists will have access to dense image time series from high-spatial-resolution satellite data."

Jim Kellner, Professor, Brown University



Join more than 50 schools around the world that have invested in greater access to Planet data to support their research and classroom activities.

For more information, see go.planet.com/research

References

Asner, G. P., R. E. Martin, and J. Mascaro. 2017. Coral reef atoll assessment in the South China Sea using Planet Dove satellites. Remote Sensing in Ecology and Conservation 3(2): 57-65. doi:10.1002/rse2.42.

Bradley, K., et al. 2019. Earthquake-triggered 2018 Palu Valley landslides enabled by wet rice cultivation. Nature Geoscience 12, 935–939, doi:10.1038/s41561-019-0444-1.

Cannistra, A. F., D. E. Shean, and N. C. Cristea. 2021. High-resolution CubeSat imagery and machine learning for detailed snow-covered area. Remote Sensing of Environment 258 (112399), doi:10.1016/j.rse.2021.112399.

Chen, K. et al. 2020. Cascading and pulse-like ruptures during the 2019 Ridgecrest earthquakes in the Eastern California Shear Zone. Nature Communications 11, 22, doi:10.1038/s41467-019-13750-w.

Estes, L., et al. 2021. High resolution, annual maps of the characteristics of smallholder-dominated croplands at national scales. eartharXiv: https://eartharxiv.org/repository/view/2155/.

Csillik, O., P. Kumar, and G. P. Asner. 2020. Challenges in estimating tropical forest canopy height from Planet Dove imagery. Remote Sensing 12(7), doi:10.3390/rs12071160.

Csillik, O. et al. 2020. Monitoring tropical forest carbon stocks and emissions using Planet satellite data. Scientific Reports 9, 17831. doi:10.1038/s41598-019-54386-6.

Dixon, D. et al. 2021. Satellite prediction of forest flowering phenology. Remote Sensing of Environment 255: 112197. doi:10.1016/j.rse.2020.112197.

Huang, H. and D. P. Roy. 2021. Characterization of PlanetScope-0 PlanetScope-1 surface reflectance and normalized difference vegetation index continuity, Science of Remote Sensing. 3, 100014. doi:10.1016/j.srs.2021.100014.

Kerner, H. et al. 2020. Rapid response crop maps in data sparse regions. KDD ‘20 Humanitarian Mapping Workshop, San Diego, CA. https://arxiv.org/pdf/2006.16866.pdf.

Kikaki, A. et al. 2020. Remotely sensing the source and transport of marine plastic debris in Bay Islands of Honduras (Caribbean Sea). Remote Sensing 12(11): 1727. doi:10.3390/rs12111727.

Kirschbaum, D. et al. 2019. The state of remote sensing capabilities of cascading hazards over High Mountain Asia. Frontiers in Earth Science 7. doi:10.3389/feart.2019.00197.

Kuhn, C. et al.. 2020. Satellite and airborne remote sensing of gross primary productivity in boreal Alaskan lakes. Environmental Research Letters, 15 (105001), doi:10.1088/1748-9326/aba46f.

Li, J. et al. 2019. Adaptive bathymetry estimation for shallow coastal waters using Planet Dove satellites. Remote Sensing of Environment 232: 111302. doi:10.1016/j.rse.2019.111302.

Arches Slickrock, Grand County, Utah
April 26, 2021

Li, Z. et al. 2020. Sharpening the Sentinel-2 10 and 20 m bands to PlanetScope-0 3 m resolution. Remote Sensing 12(15), doi:10.3390/rs12152406.

Lyons, M. B. et al. 2020. Mapping the world's coral reefs using a global multiscale earth observation framework. Remote Sensing in Ecology and Conservation 6(4): 557-568. doi:10.1002/rse2.157.

Niroumand-Jadidi, M. et al. 2020. Physics-based bathymetry and water quality retrieval using PlanetScope imagery: Impacts of 2020 COVID-19 lockdown and 2019 extreme flood in the Venice lagoon. Remote Sensing 12(15), doi:10.3390/rs12152381.

Oughton, E. J. and J. Mathur. 2021. Predicting cell phone adoption metrics using machine learning and satellite imagery. Telematics and Informatics 62: 101622. doi:/10.1016/j.tele.2021.101622.

Park, J. et al. 2020. Illuminating dark fishing fleets in North Korea. Science Advances 6(30). doi:10.1126/sciadv.abb1197.

Planet Team. 2017. Planet Application Program Interface: In Space for Life on Earth. San Francisco, CA. https://api.planet.com.

Qayyum, N. et al. 2020. Glacial lakes mapping using multi satellite PlanetScope imagery and deep learning. International Journal of Geo-Information 9 (560), doi:10.3390/ijgi9100560.

Roy, D. et al. 2019. Landsat 8 and Sentinel-2 burned area mapping - A combined sensor multi-temporal change detection approach. Remote Sensing of Environment 231: 111254. doi:10.1016/j.rse.2019.111254.

Shendryk, Y. et al. 2019. Deep learning for multi-modal classification of cloud, shadow and land cover scenes in PlanetScope and Sentinel-2 imagery. ISPRS Journal of Photogrammetry and Remote Sensing 157, 124–136. doi:10.1016/j.isprsjprs.2019.08.018.

Suel, E. et al. 2021. Multimodal deep learning from satellite and street-level imagery for measuring income, overcrowding, and environmental deprivation in urban areas. Remote Sensing of Environment 257: 112339. doi:10.1016/j.rse.2021.112339.

Wang, J. et al. 2020. Multi-scale integration of satellite remote sensing improves characterization of dry-season green-up in an Amazon tropical evergreen forest. Remote Sensing of Environment 246: 111865. doi:10.1016/j.rse.2020.111865.

Wu, S. et al. 2021. Monitoring tree-crown scale autumn leaf phenology in a temperate forest with an integration of PlanetScope and drone remote sensing observations. ISPRS Journal of Photogrammetry and Remote Sensing 171: 36-48. doi:10.1016/j.isprsjprs.2020.10.017.

Zheng, T. et al. 2021. Local PM2.5 Hotspot Detector at 300 m Resolution: A Random Forest–Convolutional Neural Network Joint Model Jointly Trained on Satellite Images and Meteorology. Remote Sensing 13(7), 1356. doi:10.3390/rs13071356.

Arches Slickrock, Grand County, Utah
April 26, 2021


San Farncisco, California, USA
February 11, 2017